

TOCHNOG PROFESSIONAL User's manual
Version 23

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1 Conditions

All conditions from the Tochnog Order form apply. See our internet page for the latest order form.

2 Basic information

2.1 pdf and HTML manual

This manual comes both as pdf and HTML files. The HTML files are automatically generated; this is not always perfect, and typically the syntax of data records may contain errors. In case of trouble please always consult the pdf manual.

2.2 How to perform a calculation and how to get started

Create an input file, e.g. **problem.dat**. The default input file is **tochnog.dat**, which will be used if no other input file is specified. Thus the command **tochnog** or **tochnog tochnog.dat** yields output on the screen while **tochnog tochnog.dat > tochnog.out** redirects the output to a file. On a Unix system you can run the job in the background with **tochnog tochnog.dat > tochnog.out &**. On a Microsoft windows system you need to run from a DOS shell.

Use the **condifl.dat** test to get started.

- Copy **condifl.dat** to **tochnog.dat**.
- Use your favorite editor to open the file **tochnog.dat** and study it.
- Change **echo** to **-yes**.
- Remove the parentheses (...) surrounding the **control_print** statement and save the file.
- Run by typing **tochnog** or **tochnog tochnog** or **tochnog tochnog.dat**.
- Study the output on the screen.
- Study the **tochnog.log** file.
- Study the **tochnog.dbs** file. It contains the database after the calculation, and is an input file itself!

Read at least once the start of the data part introduction section.

2.3 Pre- and postprocessing

You can use **GID** both for preprocessing (mesh generation) and post processing (plotting). **GID** is commercially available at the **www.gidhome.com** Internet page. A free demo version of is available for download.

Alternatively to **GID** you can use **Mecway** for preprocessing and post processing. **Mecway** is commercially available at the **mecway.com** Internet page. It is very affordable, and also has build in FE calculations. It is only available on MS Windows however. A free demo version of is available for download.

You can also use **GMSH** both for preprocessing and post processing. **GMSH** is freely available at **www.geuz.org/gmsh**.

Postprocessing files are written for the visualisation program **paraview**. The **paraview** program is freely available at **www.paraview.org**.

Furthermore, postprocessing files are written for the visualisation program **tecplot**. These **tecplot** are less well maintained than the files for other postprocessing programs.

With **gnuplot** you can plot files resulting from **control_print_history** and **control_print_data_versus_data**. Also any other x-y plotting program can be used for such files.

2.4 Space discretization, time discretization

The computational domain is divided into finite elements. The elements connect at nodes. Either one-dimensional (1D), two-dimensional (2D), three-dimensional (3D) or axis-symmetrical (2D) domains can be used.

Only first order in time equations are solved. Time derivatives are approximated with Euler backward time discretization.

Tochnog professional can store strains, stresses etc. either in element integration points (jumps between elements possible) or in nodes (continuous fields between elements); see **global_element_dof_apply**.

2.5 Program capabilities

- Input
 - Format free input. Words and no 'magic numbers' in rigidly defined columns are used.
 - Boundary conditions can be imposed onto geometrical entities, as well as onto elements and nodes.
- Output/plotting
 - Output can be printed over user-specified geometrical objects (points, lines, quadrilaterals,...) as well as at nodes.
 - The history of each variable, and for functions of variables, can be printed over user-specified geometrical objects as well as at nodes.
 - Interface files for the GID pre- and post processor.
- Finite elements
 - 1D, 2D and 3D. Tochnog mostly uses isoparametric elements. There are also springs, trusses, beams and contact-springs however.
 - Linear and quadratic simplex elements (triangles, tetrahedrons). Linear and quadratic prism elements. A full family of first to fourth order bar, quadrilateral and brick elements.
- Mesh generation/refining/etc.
 - Macro regions are automatically divided into finite elements.
 - Local h-refinement
 - Global h-refinement (more elements).
 - Global p-refinement (polynomial refinement).
- Differential equations (materials)
 - Convection-diffusion equation:
 - Temperature calculations.
 - Fluids:
 - Stokes and Navier-Stokes.
 - Solids:

- Elasticity (isotropy and transverse isotropy).
- Elasto-Plasticity (Von-Mises, Mohr-Coulomb, Gurson, etc.; plasticity surfaces can be arbitrarily combined).
- Hypo-Plasticity (Von-Wolffersdorff, Masin, cohesion, intergranular strains, pressure dependent initial void ratio).
- Damage.
- Thermal stresses.
- Hypoelasticity.
- Viscoelasticity.
- Viscoplasticity.
- Viscosity.

Ground water flow equation:

- Storage equation.

Wave equation.

- Accuracy information

Residues in equations can be printed/plotted.

Error estimates for all data (stresses, forces, temperatures, etc.)

- Interaction analysis

Automatic fluid-solid interaction.

Temperature effects on fluids, solids.

- Contact analysis

Contact with and without friction.

Frictional heat generation.

- Bond slip

Slip between reinforcement bars and concrete

- Frames of description

Lagrangian and Eulerian (Eulerian not for plasticity calculations)

- Types of analysis

Static, quasi-static and dynamic analysis.

- Parallelization

The following functionality is parallelized

- element nodal force calculation.
- contact algorithm.
- mapping of state variables when building a new mesh.
- determination of boundary conditions.
- iterative linear equations solver (diagonal preconditioned biconjugate gradient solver).
- external pardiso linear equations solver (direct solver; threads and openmp based parallelization).
- etc.

- Special features

Automatic time-stepping (large steps for good iteration behavior, small steps for bad iteration behavior).

Automatic distribution of tendon trusses over finite elements (automatic embedment).

Inverse modeling (estimation of model parameters).

Restart possibility.

Convection wiggle stabilization (both for low and high order elements).

2.6 Files used by Tochnog

- Input file. For example **condif1.dat**. The input file consists of an initialization part (which dof's should be solved, etc.) and a data part (elements, nodes, etc.).
- Runtime input file. For example **condif1.run**. Use it to give Tochnog data records on the fly (while it is running).
- Plot files. For example **condif1_flavia.msh** and **condif1_flavia.res**.
- Database file. For example, after the calculation with input file **condif1.dat** the database file **condif1.dbs** will be written. It contains everything (nodes, elements, solutions fields, etc.). On error exit for example **condif1_error.dbs** will be generated.
- Scratch file **tochnog_tmp.txt**. Don't use this name yourself.
- Log file **tochnog.log**. Contains log messages of calculations.

3 Equations

3.1 Convection and diffusion of heat

3.1.1 Convection-diffusion equation

$$\rho C(\dot{T} + \beta_i \frac{\partial T}{\partial x_i}) = k_i \frac{\partial^2 T}{\partial x_i^2} - aT + f$$

The primary dof is the **condif.temperature** T . Further notation: ρ **group_condif_density**; C **group_condif_capacity**; x space coordinate; β_i **group_condif_flow** in i -direction; k_i **group_condif_conduct** in i -direction; a **group_condif_absorption**; f **condif_heat_volume**. Typical applications are heat conduction and heat conduction in a flow.

3.1.2 Convection to environment

$$q_c = \alpha_c(T - T_c)$$

Here q_c is the **condif.convection_edge_normal** heat flux, α_c is the convection coefficient and T_c is the environmental temperature for convection.

3.1.3 Radiation to environment

$$q_r = \alpha_r(T^4 - T_r^4)$$

Here q_r is the **condif.radiation_edge_normal** heat flux, α_r is the radiation coefficient and T_r is the environmental temperature for radiation.

3.2 Material deformation and flow

$$\rho \dot{v}_i = \frac{\partial \sigma_{ij}}{\partial x_j} + (1 - \beta T) \rho g_i - d v_i + f_i$$

Notations: ρ **group_materi_density**; v_i **materi_velocity** in i -direction; σ_{ij} **materi_stress** matrix; x space coordinate; β **group_materi_expansion_volume**; T (optional) **condif_temperature**; g_i **force_gravity**; d is the **group_materi_damping** coefficient; f_i **force_volume**. The equation is given for space coordinates following the material velocities v_i .

TOCHNOG allows you to build your favorite material, by adding separate contributions to the stresses σ_{ij} . In this way you can build solids or fluids or things in between. The separate contributions will be listed below. First two typical examples are given.

Nearly incompressible Navier Stokes:

```
...
materi_velocity
materi_stress
end_initia
...
mesh -fixed_in_space -fixed_in_space
timestep_predict_velocity 0 -yes
...
group_type 0 -materi
group_materi_elasti_compressibility 0 1.0
group_materi_viscosity 0 1.2
...
```

Linear solid:

```
...
materi_velocity
materi_strain_total
materi_stress
end_initia
...
group_type 0 -materi
group_materi_elasti_young 0 1.e10
group_materi_elasti_poisson 0 0.2
group_materi_memory 0 -updated_linear
```

3.2.1 Memory

The -updated Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. TOCHNOG decomposes the incremental deformation tensor with a polar decomposition into $F = RU$ with F the incremental deformation matrix, R the incremental rotation matrix and

U the incremental stretch matrix. The incremental stretch matrix U is used to determine the incremental strain matrix $0.5(U + U^T) - I$ with I the identity tensor. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point
- rotate these new stresses by the matrix R

The **-updated_jaumann** Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. The incremental stretch matrix U is used to determine the incremental strain matrix $0.5(F + F^T) - I$ with I the identity tensor. The incremental rotation matrix R is $0.5(F - F^T) + I$. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point
- rotate these new stresses by the matrix R

The **-updated_linear** Lagrange formulation

Deformations (i.e. the incremental deformation matrix F) refers to the previous time point. Any rigid body rotation between the two time points are neglected, so TOCHNOG decomposes the incremental deformation tensor with a polar decomposition into $F = U$ with F the incremental deformation matrix, and U the incremental stretch matrix. The linear engineering strains in the deformed configuration are used as incremental strain matrix $0.5(F + F^T) - I$. The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point

The **-total** Lagrange formulation

Deformations (i.e. the total deformation matrix F) refers to the time 0. TOCHNOG decomposes the total deformation tensor with a polar decomposition into $F = RU$ with F the total deformation matrix, R the total rotation matrix and U the total stretch matrix. The total stretch matrix U is used to determine the total strain matrix $0.5(U + U^T) - I$ with I the identity tensor. The stresses at a new timepoint are calculated as:

- back-rotate the old stresses at the previous time point to time 0 with the old rotation matrix
- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the back-rotated old stresses of the previous time point
- rotate the added stresses with the new rotation matrix R to the new configuration

The **-total_linear** Lagrange formulation

Deformations (i.e. the total deformation matrix F) refers to the time 0. TOCHNOG neglects any rigid body rotations and uses linear engineering strains $0.5(F + F^T) - I$. The difference in these linear engineering strains between two time points are the incremental strains.

The stresses at a new timepoint are calculated as:

- calculate extra stresses due to incremental strain matrix
- add these extra stresses to the stresses of the previous time point

See also **group_materi_memory**.

3.2.2 Elasticity

The elastic stress rate is

$$C_{ijkl}\dot{\epsilon}_{kl}^{\text{elas}}$$

where C_{ijkl} is the elastic modulus tensor (which is a doubly symmetric tensor: $C_{ijkl} = C_{jikl}$, $C_{ijkl} = C_{ijlk}$ and $C_{ijkl} = C_{jilk}$), and $\dot{\epsilon}_{kl}^{\text{elas}}$ is the elastic strain rate. See the plasticity section for a definition of the elastic strain rate.

For an isotropic material

$$\begin{aligned} C_{0000} &= C_{1111} = C_{2222} = \frac{E(1-\nu)}{(1+\nu)(1-2\nu)} \\ C_{0011} &= C_{0022} = C_{1122} = \frac{E\nu}{(1+\nu)(1-2\nu)} \\ C_{0101} &= C_{0202} = C_{1212} = \frac{E}{1+\nu} \end{aligned}$$

with E **group_materi_elasti_young** modulus and ν **group_materi_elasti_poisson** ratio (the remaining non-zero moduli follow from the double symmetry conditions).

For a transverse isotropic material the material has one unique direction (think of an material with fibers in one direction). Here we take '2' as the unique direction; '1' and '3' are the transverse directions. The material is fully defined by E_1 , E_2 , ν_1 , ν_2 , and G_2 . This set of parameters leads directly to a set of elasticity coefficients C_{ijkl} . The parameters can be given in **group_materi_elasti_transverse_isotropy**,

The nonlinear elasticity polynomials is a strain dependent model. In this model, the 'young's stiffness' modulus is made dependent of the size of the strains via a series of polynomials

$$E = E_0 + E_1\epsilon^1 + E_2\epsilon^2 + \dots \quad (1)$$

where

$$\epsilon = \sqrt{(\epsilon_{ij}\epsilon_{ij})} \quad (2)$$

with ϵ_{ij} the components of the strain matrix. The parameters E_0 etc. need to be specified in the **group_materi_elasti_young_polynomial** record.

The power law nonlinear elasticity is a stress dependent model which typically is used to model the elastic behavior of granular materials. It can be combined with plastic models, for example with the di Prisco plasticity model for soils, and with a poisson ratio.

In this model, the 'young's stiffness' modulus is made a function of the average stress state:

$$E = E_0(p/p_0)^\alpha \quad (3)$$

where p is the pressure. Furthermore, E_0 is the reference stiffness at reference pressure p_0 , and α is a soil dependent power coefficient. The parameters E_0 , p_0 , and α need to be specified in the **group_materi_elasti_young_power** record.

The stiffness matrix C_{ijkl} for the Borja Tamagnini nonlinear elasticity model is specified in

The model contains G_0 , α , \hat{k} and p_r as user specified constants which need to be specified in the **group_materi_elasti_borja_tamagnini** record.

The Lade nonlinear elasticity is a stress dependent model which typically is used to model the elastic behavior of granular materials. It can be combined with plastic models, for example with the di Prisco plasticity model for soils.

The stress rates are linked to the strain rates by the equation:

$$\dot{\epsilon}_{ij} = \frac{\partial W^2}{\partial \sigma_{ij} \partial \sigma_{hk}} \dot{\sigma}_{hk} \quad (4)$$

where the function W is

$$W = \frac{X^{1-\lambda}}{2B(1-\lambda)}$$

where

$$X = p^2 + R^* \text{abs}(s_{ij}s_{ij})$$

with pressure $p = (\sigma_{11} + \sigma_{22} + \sigma_{33})/3$ and deviatoric stresses $s_{ij} = \sigma_{ij} - p\delta_{ij}$.

The model contains three user specified constants B , R , λ which need to be specified in the **group_materi_elasti_lade** record. B and λ are defined by means of an isotropic unloading test, and R by means of an unloading-standard-triaxial-compression test. For example for a loose sand $B = 1028$, $R = 0.25$, $\lambda = 0.28$. See [8] for the details.

The model cannot be used in combination with a poisson ratio.

3.2.3 Elasto-Plasticity

Plastic strain

In plastic analysis, the **materi_strain_elasti** rate follows by subtracting from the **materi_strain_total** rate the **materi_strain_plasti** rate

$$\dot{\epsilon}_{ij}^{\text{elas}} = \dot{\epsilon}_{ij} - \dot{\epsilon}_{ij}^{\text{plas}}$$

where the **materi_strain_total** rate is

$$\epsilon_{ij} = 0.5 \left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} \right)$$

The **materi_strain_plasti** rate follows from the condition that the stress cannot exceed the yield surface. This condition is specified by a yield function $f^{\text{yield}}(\sigma_{ij}) = 0$. The direction of the plastic strain rate is specified by the stress gradient of a flow function $\frac{\partial f^{\text{flow}}}{\partial \sigma_{ij}}$. If the yield function and flow function are chosen to be the same, the plasticity is called associative, otherwise it is non-associative.

Von-Mises is typically used for metal plasticity. Mohr-Coulomb and Drucker-Prager are typically used for soils and other frictional materials. *The plasticity models can freely be combined; the combination of the plasticity surfaces defines the total plasticity surface.*

Typically, if you use Mohr-Coulomb or Drucker-Prager to model shear failure for soils, you should use the tension limiting model to limit tension stresses, preferably **group_materi_plasti_tension_direct**.

First some stress quantities which are used in most of the plasticity models are listed.

Equivalent Von-Mises stress:

$$\bar{\sigma} = \sqrt{\frac{s_{ij}s_{ij}}{2}}$$

Mean stress:

$$\sigma_m = \frac{\sigma_{11} + \sigma_{22} + \sigma_{33}}{3}$$

Deviatoric stress:

$$s_{ij} = \sigma_{ij} - \sigma_m \delta_{ij}$$

CamClay plasticity model

Here we provide the equations of the Cam Clay model (Roscoe and Burland, 1968, summarized e.g. by Wood, 1990, see [19]). All stresses are effective (geotechnical) stresses, i.e. compression is positive! Definitions of variables:

$$p = (\sigma_1 + \sigma_2 + \sigma_3)/3$$

$$q = \left\{ \frac{1}{2} [(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2] \right\}^{1/2}$$

in the principal stress axes. The CamClay yield rule, which is also the flow rule, reads:

$$f = g = q^2 - M^2[p(p_0 - p)] = 0$$

M is a soil constant and p_0 is a history (hidden) variable which corresponds to the preconsolidation mean pressure. The hardening function, evolution, of p_0 reads:

$$dp_0 = \frac{p_0(1+e)d\varepsilon_v^p}{\lambda - \kappa}$$

in which

$$d\varepsilon_v^p = d\varepsilon_{11}^p + d\varepsilon_{22}^p + d\varepsilon_{33}^p$$

and λ and κ are user specified soil constants. Further e is the void ratio with the evolution equation:

$$de = -d\varepsilon_v(1 + e)$$

in which

$$d\varepsilon_v = d\varepsilon_{11} + d\varepsilon_{22} + d\varepsilon_{33}$$

The poisson ratio ν reads:

$$\nu = \frac{3K - 2G}{2G + 6K}$$

in which the elastic bulk modulus K is given by:

$$K = (1 + e)p/\kappa$$

and the Young's modulus E :

$$E = 2. * G * (1 + \nu)$$

in which G is a user specified soil constant, By using this ν and E the classical isotropic stress-strain law is used to calculate the stresses.

The soil constants M , κ , λ need to be specified in **group_materi_plasti_camclay**. The soil constant G , need to be specified in **group_materi_elasti_camclay_g**. For an alternative see **group_materi_elasti_camclay_poisson**. The history variables e , p_0 need to be initialized by **materi_plasti_camclay_history** record (and given initial values in **node_dof** records).

Remark 1: An additional parameter N can be often found in textbooks on the Cam Clay model. We don't include it since it is linked to other model parameters via:

$$1 + e = N - \lambda \ln p_0 + \kappa \ln(p_0/p)$$

Remark 2: If you apply a geometrical linear analysis, see section 8.4, then also the calculation of de void ratio development is linearized, and so will contain some error as compared to the exact void ratio change. Hence for very large deformations, say above 10 percent or so, don't use such geometrical linear analysis.

Cap1 plasticity model

This **group_materi_plasti_cap1** model is the first cap model that accounts for permanent plastic deformations under high pressures for granular materials. It is intended to be used in combination with shear plasticity models like Drucker-Prager, Mohr-Coulomb, etc.

First the average stress p and the equivalent shear stress q are introduced:

$$p = -(\sigma_{11} + \sigma_{22} + \sigma_{33})/3$$

$$q = \left\{ \frac{1}{2} [(\sigma_{11} - \sigma_{22})^2 + (\sigma_{22} - \sigma_{33})^2 + (\sigma_{33} - \sigma_{11})^2] + 3(\sigma_{12}^2 + \sigma_{23}^2 + \sigma_{31}^2) \right\}^{1/2}$$

These are used to define the cap plastic yield function:

$$f = \frac{q^2}{M^2} + p^*(p^* - p_c^*)$$

where

$$p^* = p + c \cot \phi \quad p_c^* = p_c + c \cot \phi$$

The parameter p_c is a history variable of this model. The parameter ϕ is the coulomb friction angle, and c is the cohesion. The parameter M denotes the tangent of the Critical State Line in the model, Typically you can use:

$$M = \frac{6 \sin \phi}{3 - \sin \phi}$$

The history parameter p_c is assumed to harden with the cap plastic volume strain rate according to the rate form:

$$\dot{\epsilon}_{cv}^p = \frac{\lambda^*/\kappa^* - 1}{K^{ref}} \left(\frac{p^{ref}}{p_c^*} \right)^m \dot{p}_c$$

Here κ^* is the swelling index (e.g. 0.03), λ^* is the compression index (e.g. 0.15), K^{ref} is the bulk modulus at stress p^{ref} (typically $100kPa$), which typically can be taken as: $K^{ref} = \frac{E^{ref}}{3(1-2\nu)}$, and finally m is an exponent (e.g. 0.6).

Initialize **materi_plasti_cap1_history** in the initialization part. The state variable p_c for this hardening soil model enters the **node_dof** records. You need to give an initial value for it in the **node_dof** records. See also [2].

Cap2 plasticity model

This is the second cap model that accounts for permanent plastic deformations under high pressures for granular materials. It is intended to be used in combination with shear plasticity models like Drucker-Prager, Mohr-Coulomb, etc.

First a deviatoric stress measure t and hydrostatic stress measure p are defined

$$t = \sqrt{3}\bar{\sigma}$$

$$p = -\sigma_m$$

See above for $\bar{\sigma}$ and σ_m . The yield rule for the **group_materi_plasti_cap2** model reads:

$$f = \sqrt{(p - p_a)^2 + \left[\frac{Rt}{(1 + \alpha - \frac{\alpha}{\cos \phi})} \right]^2} - R(c + p_a \tan \phi)$$

Here c is the cohesion and ϕ is the friction angle which should be taken equal to the values in the shear flow rule which you use. The parameter p_a follows from

$$p_a = \frac{p_b - Rc}{1 + R \tan \phi}$$

where the hydrostatic compression yield stress p_b is to be defined with an table of volumetric plastic strains ϵ_v^p versus p_b with $\epsilon_v^p = \epsilon_{11}^p + \epsilon_{22}^p + \epsilon_{33}^p$. As always, positive strain denote extension whereas negative strains denote compression.

Associative flow is used, so the flow rule is taken equal to the yield rule.

Summarizing the **group_materi_plasti_cap2** model needs as input the cohesion c , the friction angle ϕ , the parameter α (typically $1 \cdot 10^{-2}$ up to $5 \cdot 10^{-2}$), and a table ϵ_v^p versus p_b .

Compression limiting plasticity model

This **group_materi_plasti_compression** model uses a special definition for the equivalent stress

$$\bar{\sigma} = \sqrt{\sigma_{min}^2}$$

where σ_{min} is the largest compressive principal stress. The model now reads

$$\bar{\sigma} - \sigma_y = 0$$

This plasticity surface limits the allowed compressive stresses.

di Prisco plasticity model

The di Prisco model is an non-associative plastic model for soils, which can be typically combined with the 'Lade elastic model'. This di Prisco model is a rather advanced soil model, which is explained in more detail in [3] and [7]. The yield rule reads:

$$f = 3\beta_f(\gamma - 3) \ln \left(\frac{r}{r_c} \right) - \gamma J_{3\eta^*} + \frac{9}{4}(\gamma - 1)J_{2\eta^*}$$

and the flow rule yields:

$$g = 9(\gamma - 3) \ln \left(\frac{r}{r_g} \right) - \gamma J_{3\eta^*} + \frac{9}{4}(\gamma - 1)J_{2\eta^*}$$

This is an anisotropic model in which the first and second invariant of the stress rate η^* are defined relative to the rotation axes χ .

$$\begin{aligned} r &= \sigma_{ij} \chi_{ij} \\ J_{3\eta^*} &= \eta_{ij}^* \eta_{jk}^* \eta_{ki}^* \\ J_{2\eta^*} &= \eta_{ij}^* \eta_{ij}^* \\ \eta_{hk}^* &= \sqrt{3} \frac{s_{hk}^*}{r} \end{aligned}$$

where s^* follows from

$$s_{hk}^* = \sigma_{hk}^* - r\chi_{hk}$$

Further $r_g = 1$.

The history variables are χ_{ij} (rotation axes, 9 values), β (yield surface form factor), and r_c (preconsolidation mean pressure). The evolution laws for these history variables can be found in the papers listed above. The history variables χ_{ij} (9 values), β , r_c need to be initialized by the **group_plasti_diprisco_history 11** record (and should be given initial values in **node_dof** records). In a normally consolidated sand with isotropic initial conditions $\chi_{ij} = \frac{\delta_{ij}}{\sqrt{3}}$, $\beta = 0.0001$ and r_c equals $\sqrt{3}$ times the mean pressure.

The total model, yield rule and flow rule and evolution laws for history variables, contains a set of soil specific constants. In **group_materi_plasti_diprisco** you need to specify these constants. These constants are explained in more detail in the papers mentioned above, but here we give a short explanation. The constants $\hat{\theta}_c$, $\hat{\theta}_e$, ξ_c and ξ_e are linked to the dilatancy and the stress state during failure (standard triaxial compression and extension test in drained conditions). The constants γ , c_p , β_f and β_f^0 are defined by means of the experimental curves ($q-\epsilon_{axial}$, $\epsilon_{vol}-\epsilon_{axial}$) obtained by performing a standard compression test in drained conditions. Moreover, β_f , β_f^0 and t_p can also be determined by means of the effective-stress path obtained by performing a standard triaxial compression test in undrained conditions.

Finally b_p can be determined from an isotropic compression test. For a loose sand $\hat{\theta}_c = 0.253$, $\hat{\theta}_e = 0.0398$, $\xi_c = -0.2585$, $\xi_e = -0.0394$, $\gamma = 3.7$, $c_p = 18.$, $\beta_f = 0.5$, $\beta_f^0 = 1.1$, $t_p = 10.$, and $b_p = 0.0049$.

di Prisco plasticity model with varying density

This essentially is the same as the normal di Prisco model, but instead of one set of parameters you need to specify two sets of parameters, one of loose soil and one for dense soil. The actual applied parameters will then be interpolated from the loose parameters and dense parameters depending on the actual density of the soil. The parameters need to be specified in **group_materi_plasti_diprisco_density**.

The history variables are those of **group_materi_plasti_diprisco** and finally extra the relative density (by example 20 or 40). So there are 12 history variables in total.

Drucker-Prager plasticity model

The **group_materi_plasti_druck_prag** model reads

$$\begin{aligned} 3\alpha\sigma_m + \bar{\sigma} - K &= 0 \\ \alpha &= \frac{2\sin(\phi)}{\sqrt{3}(3 - \sin(\phi))} \\ K &= \frac{6c\cos(\phi)}{\sqrt{3}(3 - \sin(\phi))} \end{aligned}$$

Here c is the cohesion, which needs to be specified both for the yield function and the flow rule; by choosing different values non-associative plasticity is obtained.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Generalised Non Associate CamClay for Bonded Soils plasticity model

The **group_materi_plasti_generalised_non_associate_cam_clay_for_bonded_soils** is presently available for selected customers only. It is a modification of the 'Milan' model of Prof. Roberto Nova.

Gurson plasticity model

The **group_materi_plasti_gurson** model reads

$$\frac{3\bar{\sigma}^2}{\sigma_y^2} + 2q_1 f^* \cosh(q_2 \frac{3\sigma_m}{2\sigma_y}) - (1 + (q_3 f^*)^2) = 0$$

Here f^* is the volume fraction of voids. The rate equation

$$\dot{f}^* = (1 - f^*) f^* \epsilon_{kk}^{\text{plas}}$$

defines the evolution of f^* if the start value for f^* is specified. Furthermore, q_1 , q_2 and q_3 are model parameters.

Hardening-Soil model

In this section, the principal stresses are ordered such that

$$\sigma_3 > \sigma_2 > \sigma_1$$

so that σ_1 is the largest compressive stress. Likewise for the principal plastic strains:

$$\epsilon_3^p > \epsilon_2^p > \epsilon_1^p$$

First the elasticity parameters are defined. The elasticity parameters for the first loading are:

$$\text{Young's modulus} = E_{50} = E_{50}^{\text{ref}} \left(\frac{\sigma_3 + c \cot \phi}{\sigma_{50}^{\text{ref}} + c \cot \phi} \right)^m \quad \text{and Poisson's ratio} = \nu_{50}$$

The elasticity parameters for the elastic unloading and reloading are:

$$\text{Young's modulus} = E_{ur} = E_{ur}^{\text{ref}} \left(\frac{\sigma_3 + c \cot \phi}{\sigma_{ur}^{\text{ref}} + c \cot \phi} \right)^m \quad \text{and Poisson's ratio} = \nu_{ur}$$

The yield function reads:

$$f = \frac{1}{E_{50}} \frac{q}{1 - q/q_a} - \frac{2q}{E_{ur}} - \gamma^p$$

where q is the equivalent shear stress and γ^p is the equivalent plastic shear strain.

The equivalent asymptotic shear stress reads

$$q_a = \frac{q_f}{R_f}$$

in which q_f is the shear failure stress, and R_f is the failure ratio.

Specify all elasticity parameters in **group_materi_elasti_hardsoil**. Typically you have:

- E_{50}^{ref} from experiment at stress σ_{50}^{ref}
- ν_{ur} from experiment or the typical undrained value 0.495 or the typical drained value 0.3
- m from experiment or the typical value 0.5
- E_{ur}^{ref} from experiment at stress σ_{ur}^{ref} , or the typical value $3E_{50}^{ref}$
- ν_{ur} from experiment or the typical undrained value 0.495 or the typical drained value 0.2

Specify all plasticity parameters in **group_materi_plasti_hardsoil**.

- ϕ from experiment (maximum friction angle)
- c from experiment (cohesion)
- ψ from experiment (maximum dilatancy angle)
- R_f from experiment or the typical value 0.9 (failure ratio)

Initialize **materi_strain_plasti_hardsoil** in the initialization part. This causes that the **node_dof** records will be filled with the shear plastic strains. Also initialize **materi_plasti_hardsoil_history**.

You can add an initial contribution to the γ^p by setting **control_materi_plasti_hardsoil_gammap_initial** to **-yes**. This tells tochnog to create an extra contribution to γ^p exactly such that the yield function is zero-valued. This is convenient to start the calculation with hardsoil with deviatoric stresses which would have been outside the yield surface without this extra contribution. The extra addition to γ^p is saved in the record **element_intpnt_materi_plasti_hardsoil_gammap_initial** for each integration point of elements. The creation of this extra initial contribution is done in the first timestep of the timesteps of the corresponding **control_timestep** record with the same index.

See also [17] for some details. Especially notice that the model is more suited for monotonic loading than for load cycling (since it violates thermodynamics and tends to generate energy).

Matsuoka-Nakai model plasticity model

The Matsuoka-Nakai model [12] is a perfectly plastic model thus the fixed yield surface represents the failure surface as well. The model is based on experimental results with soils and can be formulated in terms of three stress invariants

$$f = I_3 + \frac{\cos^2 \phi}{9 - \sin^2 \phi} I_1 I_2 = 0$$

where

$$\begin{aligned} I_1 &= \text{tr}(\sigma_{ij}) = \sigma_{11} + \sigma_{22} + \sigma_{33} = \sigma_1 + \sigma_2 + \sigma_3 = 3\sigma_m \\ I_2 &= \frac{1}{2} (\text{tr}(\sigma_{ik}\sigma_{kj}) - I_1^2) = -\sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1 \\ I_3 &= \det(\sigma_{ij}) = \sigma_1\sigma_2\sigma_3 \end{aligned}$$

σ_1, σ_2 and σ_3 are the principal stresses (all stresses are effective; compressive stresses are negative). The parameter ϕ is equal to the angle of internal friction in axisymmetric (triaxial) compression [18].

When the cohesion c is considered in the model, the yield condition is formulated for a modified stress [13]

$$\bar{\sigma}_{ij} = \sigma_{ij} - \sigma_0 \delta_{ij}$$

with

$$\sigma_0 = c \cot \phi .$$

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

This law is know to behave erratic in some situations. Usage of this law is discouraged.

Matsuoka-Nakai hardening-softening plasticity model

The **group_materi_plasti_matsuoka_nakai_hardening_softening** model is the same as the standard Matsuoka-Nakai model. However, the parameters c and ϕ (both for the yield rule and for the flow rule) are softened on the effective plastic strain κ^{shear} .

For example, for the cohesion a linear variation is taken between the initial value c_0 at $\kappa^{shear} = 0$, up to c_1 at a specified critical value of κ^{shear} , and constant c_1 for larger values of κ^{shear} . The same is done for ϕ for the yield rule and for the flow rule.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Mohr-Coulomb plasticity model

The **group_materi_plasti_mohr_coul** model reads

$$0.5(\sigma_1 - \sigma_3) + 0.5(\sigma_1 + \sigma_3) \sin(\phi) - c \cos(\phi) = 0$$

Here c is the cohesion, σ_1 is the largest principal stress and σ_3 is the smallest principal stress. The angle ϕ needs to be specified for both the yield condition and the flow rule; by choosing different values, non-associative plasticity is obtained.

As an alternative consider using **group_materi_plasti_mohr_coul_direct**, which is more stable and fast.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Mohr-Coulomb hardening-softening plasticity model

The **group_materi_plasti_mohr_coul_hardening_softening** model is the same as the standard Mohr-Coulomb model. Now, however, the parameters c and ϕ (both for the yield rule and for the flow rule) are softened on the effective plastic strain κ^{shear} .

For example, for the cohesion a linear variation is taken between the initial value c_0 at $\kappa^{shear} = 0$, up to c_1 at a specified critical value of κ^{shear} , and constant c_1 for larger values of κ^{shear} . The same is done for ϕ for the yield rule and for the flow rule.

You should also include tension cut-off, preferably with **group_materi_plasti_tension_direct**.

Multilaminate plasticity model

Plastic yield function.

The multi-laminate model predefines a number of weak planes, which have reduced plasticity

parameters as compared to the bulk material. The numerical model will thus have the tendency to start slipping on the weak planes first, just like physical reality with weak planes. In fact, the yield function for each laminate amounts to a standard mohr-coulomb slip condition with predefined slip plane. The model reads

$$f_k = (|\sigma_{pq}| + \sigma_{qq} \tan(\phi) - c)_k$$

where p denotes the in-plane direction of a laminate, q denotes the normal direction of the laminate, ϕ denotes the friction angle of the laminate, c is the cohesion in the laminate, and finally k is the laminate number. The direction p is taken such in the plane of the laminate, that σ_{pq} is the maximum shear stress in the laminate plane. The stress σ_{qq} is normal to the laminate plane. The user needs to specify a normal vector n_{qk} to the plane of laminate k , so that the plane of the laminate is precisely defined.

Plastic flow rule.

To allow for non-associated plastic flow, a dilatancy angle ψ is used:

$$g_k = (|\sigma_{pq}| + \sigma_{qq} \tan(\psi) - c)_k$$

where again k denotes the number of the Multilaminate.

Elasto-plastic versus elasto-viscoplastic.

The multi-laminate plasticity model can be used elasto-plastic, but can also be used with viscoplasticity (time-dependent plasticity). In the latter case, you can apply the input data

group_materi_plasti_visco_power_name and
group_materi_plasti_visco_power_value.

Tension cutoff in laminates

To allow for laminate crack opening, you can specify a tension cutoff limit as yield function:

$$f_k = (\sigma_{qq} - \sigma_t)_k$$

where σ_t is the maximum allowable tension stress, and k is again the laminate number. Specify this model with the input data **group_materi_plasti_laminate0_tension**.

Initialisation multi-laminate model

You always need to initialise **materi_plasti_laminate** with the number of required laminates.

Optionally initialise **materi_strain_plasti_laminate_mohr_coul** etc. if you want to see the mohr-coulomb slip strains in the laminates.

Optionally initialise **materi_strain_plasti_laminate_tension** etc. if you want to see tension cutoff strains in the laminates,

Status of laminates

The status of the mohr-coulomb yield condition in the integration points of elements can be found after a calculation in **element_intpnt_plasti_laminate0_mohr_coul_status** etc. Likewise, the status of the tension yield condition can be found in **element_intpnt_plasti_laminate0_tension_status** etc.

Tension limiting plasticity model

This **group_materi_plasti_tension** model uses a special definition for the equivalent stress

$$\bar{\sigma} = \sqrt{\sigma_{max}^2}$$

where σ_{max} is the largest principal tension stress.

$$\bar{\sigma} - \sigma_y = 0$$

This plasticity surface limits the allowable tension stresses.

A simple model for concrete can be obtained as follows. Use **group_materi_plasti_tension** to limit the tension strength ft . Use **group_materi_plasti_vonmises** to limit the compressive strength fc . The tension strength could be softened to zero over an effective plastic strain κ of, say, 1 percent. The compressive strength could be softened to zero over an effective plastic strain κ of, say, 10 percent.

Von-Mises plasticity model

The **group_materi_plasti_vonmises** model reads

$$\sqrt{3} \bar{\sigma} - \sigma_y = 0$$

where without hardening the yield value is fixed $\sigma_y = \sigma_{y0}$.

If however the **group_materi_plasti_vonmises_nadai** hardening law for Von-Mises plasticity is specified then

$$\sigma_y = \sigma_{y0} + C(\kappa_0 + \kappa)^n$$

where C , κ_0 and n are parameters for the hardening law, and κ is the isotropic hardening parameter (see later). The parameter σ_{y0} is specified by **group_materi_plasti_vonmises**.

Isotropic Hardening and softening

The size of the total plastic strains rate is measured by the **materi_plasti_kappa** parameter

$$\dot{\kappa} = \sqrt{0.5 \dot{\epsilon}_{ij}^{plas} \dot{\epsilon}_{ij}^{plas}}$$

The size of the shear plastic strains rate is measured by the **materi_plasti_kappa_shear** parameter

$$\dot{\kappa}^{shear} = \sqrt{0.5 \dot{\epsilon}_{ij}^{shear, plas} \dot{\epsilon}_{ij}^{shear, plas}}$$

where the plastic shear strains are defined by

$$\dot{\epsilon}_{ij}^{shear, plas} = \dot{\epsilon}_{ij}^{plas} - \delta_{ij}(\dot{\epsilon}_{11}^{plas} + \dot{\epsilon}_{22}^{plas} + \dot{\epsilon}_{33}^{plas})/3$$

These parameters κ and κ^{shear} can be used for isotropic hardening. Use the **dependency_diagram** for this.

Kinematic Hardening

The **materi_plasti_rho** matrix ρ_{ij} , governs the kinematic hardening in the plasticity models. It is used in the yield rule and flow rule to get a new origin by using the argument $\sigma_{ij} - \rho_{ij}$:

$$\begin{aligned} f^{\text{yield}} &= f^{\text{yield}}(\sigma_{ij} - \rho_{ij}) \\ f^{\text{flow}} &= f^{\text{flow}}(\sigma_{ij} - \rho_{ij}) \end{aligned}$$

where the rate of the matrix ρ_{ij} is taken to be

$$\dot{\rho}_{ij} = a \dot{\epsilon}_{ij}^{\text{plas}}$$

where a is a user specified factor (see **group_materi_plasti_kinematic_hardening**).

Plastic heat generation

The plastic energy loss can be partially turned into heat rate per unit volume q :

$$q = \eta \sigma_{ij} \dot{\epsilon}_{ij}^{\text{plas}}$$

where η is a user specified parameter (between 0 and 1) specifying which part of the plastic energy loss is turned into heat (see **group_materi_plasti_heat_generation**).

3.2.4 Hypo-Plasticity

In hypoplasticity a direct relation is used between strain rates and effective stress rates. Rigid body rotations (objectivity) are treated elsewhere (see the section on memory). The effective stress tensor σ_{ij} follows from the total stress tensor σ_{ij} minus any pore pressures (see groundflow). The Masin law is tuned to clays. The Wolffersdorff law is tuned to sands. The Niemunis visco law describes time dependent soil behaviour.

Masin law

The law proposed by MASIN [10] and [11] is used. This law is formulated in kPa; you need to make the remainder of the input file consistent with that.

The constitutive equation in rate form reads:

$$\dot{\mathbf{T}} = \mathcal{L} : \mathbf{D} + f_d \mathbf{N} \|\mathbf{D}\| \quad (5)$$

where \mathbf{D} is the Euler's stretching tensor, \mathbf{T} is the Cauchy stress tensor and

$$\mathcal{L} = 3f_s \left(c_1 \mathcal{I} + c_2 a^2 \hat{\mathbf{T}} \otimes \hat{\mathbf{T}} \right) \quad \mathbf{N} = \mathcal{L} : \left(-Y \frac{\mathbf{m}}{\|\mathbf{m}\|} \right) \quad \hat{\mathbf{T}} = \frac{\mathbf{T}}{\text{tr } \mathbf{T}} \quad (6)$$

$\mathbf{1}$ is the second-order identity tensor and \mathcal{I} is the fourth-order identity tensor, with components:

$$(\mathcal{I})_{ijkl} = \frac{1}{2} (1_{ik}1_{jl} + 1_{il}1_{jk}) \quad (7)$$

The functions $f_s(\text{tr } \mathbf{T})$ (*barotropy factor*) and $f_d(\text{tr } \mathbf{T}, e)$ (*pyknotropy factor*) are given by:

$$f_s = -S_i \frac{\text{tr } \mathbf{T}}{\lambda^*} \left(3 + a^2 - 2^\alpha a \sqrt{3}\right)^{-1} f_d = \left[-\frac{2 \text{tr } \mathbf{T}}{3 s p_r} \exp \left(\frac{\ln(1+e) - N}{\lambda^*} \right) \right]^\alpha \quad (8)$$

where p_r is the reference stress for the parameter N , typically taken as 1 kPa, and the factor S_i is a function of sensitivity s :

$$S_i = \frac{s - k(s - s_f)}{s} \quad (9)$$

The scalar function Y and the second-order tensor \mathbf{m} are given, respectively, by:

$$Y = \left(\frac{\sqrt{3}a}{3 + a^2} - 1 \right) \frac{(I_1 I_2 + 9 I_3) (1 - \sin^2 \varphi_c)}{8 I_3 \sin^2 \varphi_c} + \frac{\sqrt{3}a}{3 + a^2} \quad (10)$$

in which:

$$I_1 = \text{tr } \mathbf{T} \quad I_2 = \frac{1}{2} [\mathbf{T} : \mathbf{T} - (I_1)^2] \quad I_3 = \det \mathbf{T}$$

and

$$\mathbf{m} = -\frac{a}{F} \left[\hat{\mathbf{T}} + \hat{\mathbf{T}}^* - \frac{\hat{\mathbf{T}}}{3} \left(\frac{6 \hat{\mathbf{T}} : \hat{\mathbf{T}} - 1}{(F/a)^2 + \hat{\mathbf{T}} : \hat{\mathbf{T}}} \right) \right] \quad (11)$$

in which:

$$\hat{\mathbf{T}}^* = \hat{\mathbf{T}} - \frac{1}{3} \quad F = \sqrt{\frac{1}{8} \tan^2 \psi + \frac{2 - \tan^2 \psi}{2 + \sqrt{2} \tan \psi \cos 3\theta}} - \frac{1}{2\sqrt{2}} \tan \psi \quad (12)$$

$$\tan \psi = \sqrt{3} \|\hat{\mathbf{T}}^*\| \quad \cos 3\theta = -\sqrt{6} \frac{\text{tr}(\hat{\mathbf{T}}^* \cdot \hat{\mathbf{T}}^* \cdot \hat{\mathbf{T}}^*)}{(\hat{\mathbf{T}}^* : \hat{\mathbf{T}}^*)^{3/2}} \quad (13)$$

Finally, the scalars a , α , c_1 and c_2 are given as functions of the material parameters φ_c , λ^* , κ^* and r by the following relations:

$$a = \frac{\sqrt{3}(3 - \sin \varphi_c)}{2\sqrt{2} \sin \varphi_c} \quad \alpha = \frac{1}{\ln 2} \ln \left[\frac{\lambda^* - \kappa^* S_i}{\lambda^* + \kappa^* S_i} \left(\frac{3 + a^2}{a\sqrt{3}} \right) \right] \quad (14)$$

$$c_1 = \frac{2(3 + a^2 - 2^\alpha a \sqrt{3})}{9r S_i} \quad c_2 = 1 + (1 - c_1) \frac{3}{a^2} \quad (15)$$

Evolution of the state variables e (void ratio) and s (sensitivity) is governed by

$$\dot{e} = (1 + e) \text{tr } \mathbf{D} \quad (16)$$

$$\dot{s} = -\frac{k}{\lambda^*} (s - s_f) \sqrt{(\dot{e}_v)^2 + \frac{A}{1 - A} (\dot{e}_s)^2} \quad (17)$$

where $\dot{e}_v = \text{tr } \mathbf{D}$ and $\dot{e}_s = \sqrt{2/3} \|\text{dev } \mathbf{D}\|$.

The basic hypoplastic model requires five constitutive parameters, namely φ_c , λ^* , κ^* , N and r , state is characterised by the Cauchy stress \mathbf{T} and void ratio e .

An extended model allows us to take into account the effects of meta-stable structure of natural clays. This extension requires three additional parameters (k , A , s_f), and one additional state variable s . A basic model without the structure effects is recovered if $s = s_f = 1$ and $A \neq 1$. The s should be always greater or equal to 1.

The basic law parameters should be specified in **group_materi_plasti_hypo_masin**. The extended parameters for the structure should be specified in **group_materi_plasti_hypo_masin_structure**.

	φ_c	λ^*	κ^*	N	r	k	A	s_f
London clay	22.6°	0.11	0.016	1.375	0.4	-	-	-
Pisa clay	21.9°	0.14	0.0075	1.56	0.3	0.4	0.1	1

Table 1: *Typical parameters of the hypoplastic model for clays.*

The hypoplastic history variables, e for this basic model, and e and s for the extended model, should be initialised with **materi_plasti_hypo_history**. As an alternative to specify the e you can specify the OCR at the start of the calculation in **group_materi_plasti_hypo_masin_ocr** (which is used to determine the initial e via $e = \exp(N - \lambda^* \ln(|OCR|) - \lambda^* \ln(|p/p_r|)) - 1$).

Wolffersdorff law

The law proposed by WOLFFERSDORFF [18] is used.

$$\dot{\sigma}_{ij} = L_{ijkl} \dot{\epsilon}_{ij} + f_d N_{ij} \sqrt{\dot{\epsilon}_{kl} \dot{\epsilon}_{kl}} = L_{ijkl} (d_{kl} - f_d Y m_{kl} ||d||)$$

Here the part with L_{ijkl} gives a linear relation between strain rates and stress rates and the part with N_{ij} gives a nonlinear relation. The constitutive tensors L_{ijkl} and $f_d N_{ij}$ are functions of the effective stress tensor σ_{ij} and void ratio e . In the above d denotes the strain rate tensor ϵ , Y denotes the degree of nonlinearity $Y = ||L^{-1} : N||$ and the flowrule m is defined by $m = -(L^{-1} : N) \rightarrow$ where a \rightarrow denotes euclidian normalisation.

$$\begin{aligned} L_{ijkl} &= f_b f_e \frac{1}{\hat{\sigma}_{mn} \hat{\sigma}_{mn}} L_{ijkl}^{\hat{}} \\ N_{ij} &= f_b f_e \frac{F a}{\hat{\sigma}_{kl} \hat{\sigma}_{kl}} (\hat{\sigma}_{ij} + \hat{\sigma}_{ij}^*) \\ \text{and } \hat{\sigma}_{ij} &= \sigma_{ij} / (\sigma_{mn} \delta_{mn}) \quad , \quad \hat{\sigma}_{ij}^* = \hat{\sigma}_{ij} - \frac{1}{3} \delta_{ij} \quad , \quad I_{ijkl} = \delta_{ik} \delta_{jl} \quad , \\ a &= \frac{\sqrt{3}(3 - \sin \varphi_c)}{2\sqrt{2} \sin \varphi_c} \\ F &= \sqrt{\frac{1}{8} \tan^2 \psi + \frac{2 - \tan^2 \psi}{2 + \sqrt{2} \tan \psi \cos 3\theta}} - \frac{1}{2\sqrt{2}} \tan \psi \quad , \\ \tan \psi &= \sqrt{3} \sqrt{\hat{\sigma}_{ij}^* \hat{\sigma}_{ij}^*} \quad , \quad \cos 3\theta = -\sqrt{6} \frac{\hat{\sigma}_{ij}^* \hat{\sigma}_{jk}^* \hat{\sigma}_{ki}^*}{[\hat{\sigma}_{mn}^* \hat{\sigma}_{mn}^*]^{3/2}} \quad . \end{aligned}$$

For the $L_{ijkl}^{\hat{}}$ above we have:

$$\hat{L}_{ijkl} = (F^2 I_{ijkl} + a^2 \hat{\sigma}_{ij} \hat{\sigma}_{kl})$$

For $\hat{\sigma}_{ij}^* = 0$ is $F = 1$.

The scalar factors f_b , f_e and f_d take into account the influence of mean pressure and density:

$$\begin{aligned} f_b &= \frac{h_s}{n} \left(\frac{e_{i0}}{e_{c0}} \right)^\beta \frac{1 + e_i}{e_i} \left(-\frac{\sigma_{ij} \delta_{ij}}{h_s} \right)^{1-n} \left[3 + a^2 - a\sqrt{3} \left(\frac{e_{i0} - e_{d0}}{e_{c0} - e_{d0}} \right)^\alpha \right]^{-1} \quad , \\ f_d &= \left(\frac{e - e_d}{e_c - e_d} \right)^\alpha \quad . \end{aligned}$$

and $f_e = \left(\frac{e_c}{e} \right)^\beta$.

Three characteristic void ratios – e_i (during isotropic compression at the minimum density), e_c (critical void ratio) and e_d (maximum density) – decrease with mean stress:

$$\frac{e_i}{e_{i0}} = \frac{e_c}{e_{c0}} = \frac{e_d}{e_{d0}} = \exp \left[- \left(- \frac{\sigma_{ij} \delta_{ij}}{h_s} \right)^n \right]$$

The range of admissible void ratios is limited by e_i and e_d . The model parameters can be found in Tab. 2. They correspond to Hochstetten sand from the vicinity of Karlsruhe, Germany [18].

φ [°]	h_s [MPa]	n	e_{c0}	e_{d0}	e_{i0}	α	β
33	1000	0.25	0.95	0.55	1.05	0.25	1.0

Table 2: *Basic hypoplastic parameters of Hochstetten sand.*

The basic law parameters should be specified in **group_materi_plasti_hypo_wolffersdorff**. The hypoplastic history variables should be initialised with **materi_plasti_hypo_history**.

Visco law

For visco hypoplasticity with intergranular strains the stress rate reads:

$$\dot{\sigma}_{ij} = M_{ijkl} \dot{\epsilon}_{kl} - L_{ijkl} \dot{\epsilon}_{kl}^{vis}$$

For visco hypoplasticity the L_{ijkl} reads:

$$L_{ijkl} = f_b \hat{L}_{ijkl}$$

where

$$f_b = \frac{-\sigma_{kk}}{(1 + a^2/3)\kappa}$$

where κ is a user specified material constant κ (= Butterfield's swelling index upon isotropic unloading), and a relates to the user specified residual (=critical) friction angle φ_c as:

$$a = \frac{\sqrt{3}(3 - \sin \varphi_c)}{2\sqrt{2} \sin \varphi_c}$$

The pressure normalised stiffness is:

$$\hat{L}_{ijkl} = F^2 I_{ijkl} + a^2 \hat{\sigma}_{ij} \hat{\sigma}_{kl} + b^2 (I_{ijkl} - \frac{1}{3} I_{ikk} I_{jll})$$

where

$$b^2 = \frac{(1 + \frac{1}{3}a^2)(1 - 2\nu)}{1 + \nu} - 1$$

Notice that the equation for b only holds true for non-negative right-hand-side, so that puts limits on the allowed values for φ_c and ν .

For visco hypoplasticity the M_{ijkl} reads:

$$\begin{aligned} M_{ijkl} &= [\rho^x m_T + (1 - \rho^x) m_R] L_{ijkl} + \\ &+ \begin{cases} \rho^x (1 - m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} > 0 \\ \rho^x (m_R - m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} \leq 0 \end{cases} \end{aligned}$$

where \hat{S} intergranular strains are the same as in the formulation without viscosity.

The viscosity strain rate is assumed to be:

$$\dot{\epsilon}_{ij}^{vis} = D_r \hat{m}_{ij} \left(\frac{1}{OCR} \right)^{\frac{1}{T_v}}$$

where the normalised flow rule \hat{m}_{ij} is

$$\hat{m}_{ij} = \frac{m_{ij}}{\sqrt{m_{ij} m_{ij}}}$$

with

$$m_{ij} = - \left[\frac{F^2}{a^2} (\hat{\sigma}_{ij} + \hat{\sigma}_{ij}^*) + \hat{\sigma}_{kl} \hat{\sigma}_{kl} \hat{\sigma}_{ij}^* - \hat{\sigma}_{ij} \hat{\sigma}_{kl} \hat{\sigma}_{kl}^* \right]$$

The over-consolidation ratio OCR appearing in the expression for the viscous creep rate is a function of the effective stress σ_{ij} and of the void ratio e

$$OCR = \frac{p_e}{p_e^+}$$

wherein the void ratio is hidden in the equivalent pressure p_e and p_e^+ is a special stress invariant.

The equivalent pressure p_e is calculated from

$$\ln \left(\frac{1 + e_{e0}}{1 + e} \right) = \lambda \ln \left(\frac{p_e}{p_{e0}} \right)$$

with a user specified material constant λ (= Butterfield's first compression index) and also user-specified reference parameters e_{e0} , p_{e0} which describe any pair of the void ratio and the effective pressure registered upon an isotropic D_r -isotach, i.e. during an isotropic first (= virgin) compression test with a constant volumetric rate of deformation equal to $-\sqrt{3}D_r \frac{\lambda}{\lambda - \kappa}$.

The stress invariant p_e^+ is calculated using

$$p_e^+ = \begin{cases} \frac{p}{\beta_R - 1} \left[\beta_R \sqrt{1 + \eta^2 (\beta_R^2 - 1)} - 1 \right] & \text{if } \eta < 1 \\ p(1 + \eta^2)^{\frac{1 + \beta_R}{2}} & \text{otherwise} \end{cases}$$

wherein

$$\eta = q/(Mp) \quad \text{and} \quad M = \frac{6F \sin \varphi_c}{3 - \sin \varphi_c}$$

where $p = -\sigma_{kk}/3$ and $q = \sqrt{\frac{3}{2} \sigma_{kl}^* \sigma_{kl}^*}$ are the popular Roscoe's stress invariants. and β_R (= flattening factor for the Rendulic's cap) are the user supplied material constants.

You can specify an initial value of the void ration e_0 in **-hyhis0** with **control_reset_dof**. Then the OCR can be calculated with the above equations. As an alternative you can specify the OCR at the start of the calculation in **group_materi_plasti_hypo_niemunis_visco_ocr**; then the initial void ratio will be calculated as follows: p_e^+ will be determined from the equation above, then p_e is determined from $p_e = OCR p_e^+$ and then the initial void ratio e_0 is determined from $e_0 = (1 + e_{e0}) * (p_e/p_{e0})^{-\lambda} - 1$. (reference: Niemunis communications). Application of the specified OCR is triggered by **control_materi_plasti_hypo_niemunis_visco_ocr_apply**.

User parameters should be specified in **group_materi_plasti_hypo_niemunis_visco**.

Cohesion extension

A simplistic approach to include cohesion is used here. Instead of feeding the real effective stress state σ_{ij} into the hypoplastic law, an alternative effective stress state σ_{ij}^c is used. Cohesion is

modeled by subtracting in each of the normal stress components a value c representing cohesion: $\sigma_{11}^c = \sigma_{11} - c$, $\sigma_{22}^c = \sigma_{22} - c$ and $\sigma_{33}^c = \sigma_{33} - c$. The shear stresses are not altered: $\sigma_{12}^c = \sigma_{12}$, etc.

The cohesion value should be specified in **group_materi_plasti_hypo_cohesion**.

Intergranular strains extension

In order to take into account the recent deformation history, an additional tensorial state variable S_{ij} ¹ is introduced.

Denoting the normalized magnitude of S_{ij}

$$\rho = \frac{\sqrt{S_{ij}S_{ij}}}{R}$$

(R is a material parameter) and the direction of S_{ij}

$$\hat{S}_{ij} = \frac{S_{ij}}{\sqrt{S_{kl}S_{kl}}}$$

($\hat{S}_{ij} = 0$ for $S_{ij} = 0$), the evolution equation for the intergranular strain tensor reads:

$$\dot{S}_{ij} = \begin{cases} (I_{ijkl} - \rho^{\beta_x} \hat{S}_{ij} \hat{S}_{kl}) \dot{\epsilon}_{kl} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} > 0 \\ \dot{\epsilon}_{ij} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} \leq 0 \end{cases} ,$$

where \dot{S}_{ij} is the objective rate of intergranular strain. Rigid body rotations are treated elsewhere (see the section on memory). From the evolution equation (3.2.4) it follows that ρ must remain between 0 and 1.

The general stress-strain relation is now written as

$$\dot{\sigma}_{ij} = M_{ijkl} \dot{\epsilon}_{kl} .$$

The fourth order tensor M_{ijkl} represents the incremental stiffness and is calculated from the hypoplastic tensors L_{ijkl} and N_{ij} which may be modified by scalar multipliers m_T and m_R , depending on ρ and on the product $\hat{S}_{ij} \dot{\epsilon}_{ij}$:

$$\begin{aligned} M_{ijkl} &= [\rho^\chi m_T + (1 - \rho^\chi) m_R] L_{ijkl} + \\ &+ \begin{cases} \rho^\chi (1 - m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} + \rho^\gamma f_d N_{ij} \hat{S}_{kl} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} > 0 \\ \rho^\chi (m_R - m_T) L_{ijmn} \hat{S}_{mn} \hat{S}_{kl} & \text{for } \hat{S}_{ij} \dot{\epsilon}_{ij} \leq 0 \end{cases} \end{aligned}$$

χ and γ are additional material parameters.

An example intergranular parameters can be found in Tab. 3.

R	m_R	m_T	β_x	χ	γ
$1 \cdot 10^{-4}$	5.0	2.0	0.50	6.0	6.0

Table 3: *Example of Intergranular hypoplastic parameters.*

The intergranular parameters should be specified in **group_materi_plasti_hypo_strain_intergranular**. Additionally you need to include **materi_strain_intergranular** in the initialisation part.

¹ S_{ij} is denoted δ_{ij} in the paper [14]. However, in order to avoid confusion with Kronecker delta, another symbol is used here.

The additional parameter gamma is very important only for the accumulation of permanent displacements or pore pressures in cyclic or dynamic analysis with small strains. For monotonic loading or higher strains gamma is not very important. And thus for such monotonic loading or higher strains you should take $\gamma = \chi$.

Pressure dependent initial void ratio extension

You can correct the initial void ratio e_0 , as specified in the initial value for the history variable in the **node_dof** records, for the initial pressure to obtain a corrected initial void ratio e .

$$\frac{e}{e_0} = \exp \left[- \left(- \frac{\sigma_{ij} \delta_{ij}}{h_s} \right)^n \right]$$

See the basic law description for the parameters h_s and n . The σ_{ij} denotes the effective stress tensor (total stresses minus any groundflow pressure). This pressure dependent initial void ratio correction can be activated by **control_materi_plasti_hypo_pressure_dependent_void_ratio**. After the initial void ratio has been established, the development of the void ratio is governed by volumetric compression or extension of the granular skeleton.

3.2.5 Damage

In the presence of **materi_damage** d , the **materi_stress** follows:

$$\sigma_{ij}^{\text{damaged}} = (1 - d) \sigma_{ij}^{\text{undamaged}}$$

For the damage, the **group_materi_damage_mazars** model is available:

$$d = d_t \alpha^\beta + d_c (1 - \alpha)^\beta$$

where

$$d_t = 1. - (1 - a_t) \frac{\epsilon^0}{\epsilon^{\text{eq}}} - a_t e^{-b_t(\epsilon^{\text{eq}} - \epsilon^0)}$$

and

$$d_c = 1. - (1 - a_c) \frac{\epsilon^0}{\epsilon^{\text{eq}}} - a_c e^{-b_t(\epsilon^{\text{eq}} - \epsilon^0)}$$

Here ϵ^{eq} contains the positive principal strains. The parameter α is given by the ratio $\frac{\epsilon^{\text{eq}}}{\epsilon}$, where ϵ contains the total strains (both negative and positive). The parameter ϵ^0 is the strain threshold for damage; other material parameters are β , a_t , b_t , a_c , b_c . Typically for concrete:

$$1.e-4 < \epsilon^0 < 3.e-4 ; \beta = 1. ; 1 < a_t < 1.5 ; 500 < b_t < 2000 ; 0.7 < a_c < 1.2 ; e^4 < b_c < 5e^4$$

You can combine damage freely with plasticity models or other material behavior.

3.2.6 Average stress (hydrostatic compressibility)

An extra average stress contribution on each of σ_{11} , σ_{22} and σ_{33} is

$$\frac{1}{co} \frac{\partial v_i}{\partial x_i}$$

where *co* is the **group_materi_elasti_compressibility**, which should not be 0. This pressure term can e.g. be used to model nearly incompressible fluids. The compressibility contribution should be combined with a contribution for the deviatoric stresses (e.g. **group_materi_viscosity**).

3.2.7 Undrained groundflow analysis

In case you want to perform an undrained groundflow analysis, but do not want to have both the material velocity and groundflow equations at the same time in system matrix, you can use **group_materi_undrained_capacity**. Then the following equation will be used to determine the total groundwater pressure changes in an element:

$$C \dot{p}_{total} = \frac{\partial v_i}{\partial x_i}$$

which actually is the groundflow storage equation without permeability. The above equation can be solved on an element-by-element level, so that the groundflow hydraulic head and the storage equation do not need to be added to the complete system matrix. The capacity *C* should be specified in **group_materi_undrained_capacity**. Results for the pressure in a element will be written to **element_intpnt_materi_undrained_pressure**. Application of this undrained analysis can be switched off and on with **control_materi_undrained_apply**.

This option is convenient to prevent the need for large, and ill-conditioned, system matrices in coupled soil - groundwater analysis. Typically the computational strategy may be like this:

```
...
(include capacity for undrained analysis in relevant groups)
group_materi_undrained_capacity ...
...
(set the hydraulic heads, and fix them for the remainder of the calculation)
control_reset_dof ...-pres
bounda_dof ...-tpres
...
(solve material displacements in the remainder of the calculation)
control_timesteps ...
control_materi_undrained_apply ... -yes
...
```

The advantage of the above computational strategy is that never a system matrix with both material velocities and groundflow pressures needs to be solved. When solving the remainder of the calculation Tochnog uses the fixed total pressure from the hydraulic heads plus the excessive undrained pressure of the remainder of the calculation as the full total pressure (when determining total stresses from effective stresses plus full total pressure). Alternatively to setting the hydraulic head at the start with the **control_reset_dof**, you can also solve the gravity state for hydraulic heads and material displacements (at the expense of a system matrix with both material velocities and groundflow hydraulic pressures in this gravity calculation; but in the gravity calculation only and the remainder of the calculation).

3.2.8 Thermal stresses

Temperature rates cause fictitious thermal strain rates

$$-\alpha \dot{T} \delta_{ij} \quad \text{where} \quad \delta_{ij} = 1 \quad \text{if} \quad i = j \quad \text{else} \quad \delta_{ij} = 0$$

where α is the **group_materi_expansion_linear** coefficient and \dot{T} is the **condif_temperature**. These fictitious thermal strain rates in turn lead to stress rates.

3.2.9 Hyper elasticity

Hyper elasticity is used to model rubbers. It should be combined with a total Lagrange formulation for the memory of the material (so use **-total** for **group_materi_memory**).

The stresses follow from a strain energy function (with C_{ij} components of the matrix C , and where F is the deformation tensor and U is the stretch tensor following from the polar decomposition of the deformation tensor)

$$2 \frac{\partial W}{\partial C_{ij}}$$

$$C = F^T F = U^T U$$

Deviatoric contributions

To obtain a purely deviatoric function, the following strain measures are used (with I_1 , I_2 and I_3 the first, second and third invariant of the elastic strain matrix C respectively)

$$J_1 = I_1 I_3^{-\frac{1}{3}} \quad J_2 = I_2 I_3^{-\frac{2}{3}}$$

The **group_materi_hyper_besseling** function reads (with K_1 , K_2 and α user defined constants)

$$W = K_1(J_1 - 3)^\alpha + K_2(J_2 - 3)$$

The **group_materi_hyper_mooney_blatz_ko** function reads (with G and β user defined constants)

$$W = G * 0.5 * (I_1 - 3.0 + (2.0/\beta)(J^{-\beta} - 1.));$$

This Blatz-Ko hyperelastic material hardens in compression, and softens slightly in tension; it models a foamlike rubber.

The **group_materi_hyper_mooney_rivlin** function reads (with K_1 and K_2 user defined constants)

$$W = K_1(J_1 - 3) + K_2(J_2 - 3)$$

The **group_materi_hyper_neohookean** function reads (with K_1 a user defined constant)

$$W = K_1(J_1 - 3)$$

The **group_materi_hyper_reduced_polynomial** function reads (with K_i user defined constants)

$$W = K_i (J_1 - 3)^i$$

where a summation over $i = 1, 2, \dots$ is applied.

Volumetric contributions

First we define $J = \sqrt{I_3}$. Then a volumetric part can be added to the strain energy.

The **group_materi_hyper_volumetric_linear** contribution reads:

$$W = \frac{K}{2} (J - 1)^2$$

The **group_materi_hyper_volumetric_murnaghan** contribution reads:

$$W = \frac{K}{\beta} \left(\frac{1}{\beta - 1} J^{-\beta} + 1 \right) J$$

The **group_materi_hyper_volumetric_polynomial** contribution reads:

$$W = \frac{K_i}{2} (J - 1)^{2i}$$

for $i = 0, 1, \dots$

The **group_materi_hyper_volumetric_simo_taylor** contribution reads:

$$W = \frac{K}{2} ((J - 1)^2 + (\ln J)^2)$$

The **group_materi_hyper_volumetric_ogden** contribution reads:

$$W = \frac{K}{\beta} \left(\frac{1}{\beta} (J^{-\beta} - 1) + \ln J \right)$$

As an example, you can combine the **group_materi_hyper_mooney_rivlin** energy function with the **group_materi_hyper_volumetric_linear** so that the total strain energy function becomes:

$$W = K_1 (J_1 - 3) + K_2 (J_2 - 3) + \frac{K}{2} (J - 1)^2$$

Here the initial shear modulus and bulk modulus are included as:

$$\text{initial shear modulus} = 2(K_1 + K_2)$$

and

$$\text{initial bulk modulus} = K$$

respectively.

3.2.10 Viscoelasticity

Viscoelasticity is modeled with n parallel **group_materi_maxwell_chains**. Each of the chains contains a spring with stiffness E^m in line with a dash pot with relaxation time t^m (m indicates the m -th maxwell chain). The viscoelastic stress rate is given by (with C_{ijkl}^m is the elastic tensor modulus of the m -th maxwell chain (depending on E^m and the poisson ratio))

$$\sum_{m=0}^{m=n-1} (C_{ijkl}^m \dot{\epsilon}_{kl}^{\text{elas}} - \frac{\sigma_{ij}^m}{t^m})$$

3.2.11 Viscoplasticity

Viscoplasticity is a model for rate-dependent plasticity. Rate dependent plasticity is important for (high-speed) transient plasticity calculations. It should be used in combination with a plasticity law. Viscoplasticity influences the stresses via the plastic strains.

The **group_materi_plasti_visco_exponential** model reads

$$\dot{\epsilon}_{kl}^{\text{plas}} = \gamma p e^{\alpha f} \frac{\partial f^{\text{flow}}}{\partial \sigma_{kl}}$$

where γ and α are material fluidity constants and p is the pressure. In case the αf becomes larger than a limit, it is substituted by the limit to prevent the exponent from becoming excessive large. You can set the limit with the **group_materi_plasti_visco_exponential_limit** record. This model was first developed for visco-plastic soil behavior.

The **group_materi_plasti_visco_power** model reads

$$\dot{\epsilon}_{kl}^{\text{plas}} = \eta(f)^p \frac{\partial f^{\text{flow}}}{\partial \sigma_{kl}}$$

where η (fluidity constant), and p (power) are user specified parameters.

3.2.12 Viscosity

The viscous contribution to the total stress is

$$2\nu D_{ij}$$

where

$$D_{ij} = 0.5 \left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} \right)$$

and divergence is neglected since we only model slightly compressible flows.

Viscous heat generation

The viscous energy loss is turned into heat rate per unit volume q :

$$q = 2\nu D_{ij}D_{ij}$$

See `group_materi_viscosity_heatgeneration`.

3.3 Bond slip

The bond slip formulation of this section is taken from [9].

3.3.1 Bond slip displacements

Nodes of trusses embedded in isoparametric mother elements can be tied with multi point constraints to the displacements of the nodes of the mother elements, see **control_mesh_truss_distribute_mpc_***. To allow for bond slip between the trusses and the isoparametric mother elements extra slip displacements s_x , s_y and s_z are introduced. Non-zero values for these slip displacements mean slip between trusses and the isoparametric elements. In the initialisation part **truss_bond_slip** should be specified.

3.3.2 Bond slip CEB-FIP 1990 Model Code 90

The extra slip displacements are determined from the condition that the bond shear stresses cannot exceed maximum allowed shear stress $\tau_{b,max}$ as a function of the size of the slip s .

$$\tau_{b,max} = \tau_{max} \left(\frac{s}{s_1} \right)^\alpha \quad 0 \leq s \leq s_1$$

$$\tau_{b,max} = \tau_{max} \quad s_1 \leq s \leq s_2$$

$$\tau_{b,max} = \tau_{max} - (\tau_{max} - \tau_f) \frac{s - s_1}{s_3 - s_2} \quad s_2 \leq s \leq s_3$$

$$\tau_{b,max} = \tau_f \quad s_3 \leq s$$

You need to specify in **group_truss_bond_slip_ceb_fip_1990** the parameters of the CEB-FIP 1990 Model Code 90.

3.3.3 Bond slip diagram

You can specify a diagram in **group_truss_bond_slip_diagram**.

3.4 Contact analysis

3.4.1 Penalty formulation

In contact analysis, normal forces F_n follow from the condition that bodies cannot penetrate each other. Since we use a penalty formulation, the normal force is given by

$$F_n = \lambda u_n$$

where u is the penetration and λ is called the **contact_penalty_velocity** because it generates forces on the velocity dof's. You can also impose **groundflow_pressure** and **condif_temperature** contact conditions by specifying the penalty factors **contact_penalty_pressure** and **contact_penalty_tempe**

3.4.2 Friction and frictional heat generation

This normal force leads to a friction force F_f which equals

$$F_f = \nu F_n$$

where ν is the *friction* coefficient (see **contact_plasti_friction**). The friction force causes heat generation rate Q :

$$Q = \eta F_f v_f$$

where v_f is the slip velocity, and the factor η is a user specified factor which determines which part of the frictional energy loss is transformed into heat (η is between 0 and 1; see **contact_heat_generation**).

3.5 Ground water flow

3.5.1 Storage equation for fully saturated analysis

The hydraulic pressure head h follows from the storage equation:

$$c \dot{h} = (k_1^p \frac{\partial^2 h}{\partial x_1^2} + k_2^p \frac{\partial^2 h}{\partial x_2^2} + k_3^p \frac{\partial^2 h}{\partial x_3^2}) + \frac{\partial v_i}{\partial x_i} - \alpha \dot{T} + f$$

Primary dof is the hydraulic pressure head **groundflow_pressure**. Further notation: c **group_groundflow_capacity**; k_i^p **group_groundflow_permeability** in i -direction (intrinsic permeability); x_i space coordinate; v_i material velocity (if present); α **group_groundflow_expansion** is the expansion coefficient of the groundwater for temperature changes. The equation is given for space coordinates following material velocities v_i (if present).

The groundflow capacity as defined in the equation above can be determined as follows. The effective bulk modulus for the soil K^s can be determined from experiments or from the young modulus and poisson ratio. The soil-water mixture bulk modulus K^m can be determined from experiments or from [20]. Thus the extra bulk modulus due to the presence of water reads $K = K^m - K^s$. And so the extra capacity c as to specified in **group_groundflow_capacity** can be calculated as $c = \frac{1}{K}$. Numerically, the groundwater capacity value is difficult to choose. Too low values leads to numerically un-stable calculations. Too high values leads to overly soft capacity. A typical value for the **group_groundflow_capacity** record when water has some little amount of dissolved air is $\frac{1}{100MPa}$.

Groundflow velocities

The groundflow velocities, after initializing **groundflow_velocity**, follow from:

$$v_i^g = k_i^p \frac{\partial h}{\partial x_i}$$

Total groundwater pressure

The total groundwater pressure, or pore-pressure, is for example needed to calculate the total stresses in soils. The total groundwater pressure follows from:

$$p_{\text{total}} = h - \rho g z$$

where g is the gravitational acceleration, and ρ is the **groundflow_density** (Please notice that g and z typically are negative numbers).

Tochnog considers pressure a pore pressure of $p = 0$, or positive, as indication that there is in fact no water pressure, so the porous soil skeleton is filled with air. In this case. the total soil stress is only composed by the effective stress of the soil skeleton.

The total stress in soils follows from: total soil stress = effective soil stress + total groundwater pressure. This will only be done for isoparametric finite elements which have groundflow data specified.

Static groundwater pressure

The static pressure due to gravity is:

$$p_{\text{static}} = \rho g \Delta z$$

where the Δz is the distance to the groundwater level, the phreatic level. The phreatic level needs to be specified with the **groundflow_phreatic_level** record. Alternatively you can specify **post_calcul_static_pressure_height**. If both **groundflow_phreatic_level** and **post_calcul_static_pressure_height** are not specified, the static pressure cannot be determined, so it remains zero.

Dynamic groundwater pressure

The dynamic groundwater pressure follows from

$$p_{\text{dynamic}} = p_{\text{total}} - p_{\text{static}}$$

Boundary conditions

If the groundwater velocity is 0 normal to an edge (say at the interface with a rock layer it is zero), then you should prescribe nothing on that edge (Tochnog will then take care of that boundary condition for you).

At the phreatic level where the groundflow meets free air the hydraulic pressure head should become $\rho g z$. You can either set this yourself by using **bounda_dof** combined with **bounda_time** or else demand that Tochnog automatically does it for you by activating the option **groundflow_phreatic_bounda**.

At edges where you have some other hydraulic head you need to specify that head yourself with **bounda_dof** and **bounda_time** records.

If gravity is not of importance, e.g. in biomechanics where the storage equation is used to model fluid transport in soft tissues, the hydraulic pressure head h is equal to the total pressure, and thus is zero at edges where the water meets the free air. In this case, set h to zero by using **bounda_dof** combined with **bounda_time**.

Postprocessing

For all printing, plotting etc. you normally get the hydraulic pressure head h since it is the primary dof solved in the storage equation. The total pressure, static pressure and dynamic pressure are obtained using the **post_calcul** option.

Naming conventions

Following conventional naming, we remind the user that the capacity depends on the porosity n and water compressibility β :

$$C = n \beta$$

and for the (intrinsic) permeability:

$$k_i^p = \frac{k_i}{\rho |g|}$$

where k_i is the hydraulic conductivity in i -direction.

3.5.2 Non-saturated analysis

with diagrams

You can perform a non-saturated analysis by making the permeability dependent on the groundwater total pressure (= pore pressure) by a dependency diagram. The diagram accounts for high

permeability at saturation and low permeability at non-saturation. For example, do something like:

```
...
dependency_item 10 -group_groundflow_permeability 0 -to_pres 4
dependency_diagram 10 -100. 0.0 0.05 100.
1.e-2 1.e-2 1.e-8 1.e-8
1.e-2 1.e-2 1.e-8 1.e-8
...
...
```

The atmospheric air pressure is 0, so that is where the permeability starts changing it's value in the table. You can also specify a table for **group_groundflow_capacity** to model non-saturated capacity.

van Genuchten

As an alternative to specifying diagrams you can use the specific van-Genuchten model for non-saturated ground water flow. The pore-pressure head is defined by

$$\phi_p = -\frac{p}{\rho g}$$

with p the pore pressure (= total pressure), ρ the ground water density and g is the absolute value of the gravity acceleration (typically 9.81). De degree of saturation is a function of the pore-pressure head

$$S = S(\phi_p)$$

The total capacity is the sum of the saturated capacity and a non-saturated part:

$$c = c_{\text{sat}} + n \frac{dS(\phi_p)}{d\phi_p}$$

where c_{sat} is the saturated groundflow capacity as specified by **group_groundflow_capacity** and n is the porosity specified by **group_porosity**. The total permeabilities k_i are written as a relative factor of the saturated permeabilities

$$k_i = k_{\text{rel}}(S) k_{\text{sat},i}$$

where k_i is the total permeability in direction i , $k_{\text{rel}}(S)$ is a factor dependent on the saturation S and $k_{\text{sat},i}$ is the saturated permeability specified by **group_groundflow_permeability**.

Now for the van-Genuchten model we have

$$S(\phi_p) = S_{\text{residu}} + (S_{\text{sat}} - S_{\text{residu}}) (1 + (g_a |\phi_p|)^{g_n})^{(1-g_n)/g_n}$$

which has the following model parameters: S_{residu} is the residual saturation, S_{sat} normally is 1.0 but may be less than 1.0 if in case of trapped air, and g_a and g_n are constants to be determined experimentally. The derivative of this law defines the additional non-saturated capacity as defined above. After definition of the effective saturation S_e

$$S_e = \frac{S - S_{\text{residu}}}{S_{\text{sat}} - S_{\text{residu}}}$$

the relative permeability factor is defined as

$$k_{\text{rel}}(S) = (S_e)^{g_l} \left(1 - (1 - S_e^{g_n/(g_n-1)})^{(g_n-1)/g_n} \right)^2$$

To use the model you need to specify the saturated parameters **group_groundflow_capacity** and **group_groundflow_permeability** as usual, specify the porosity in **group_porosity**, specify specific van-Genuchten parameters in **group_groundflow_nonsaturated_vangenuchten** and initialise **groundflow_saturation** in the initialisation part.

Since the model is strongly linear it might be needed to specify a relaxation of, say, 0.1 with **control_relaxation** to obtain convergence.

3.5.3 Consolidation analysis

Look in the 'Consolidation' section of the 'Interaction analyzes and advanced analyzes' chapter in the end of this manual on how to perform consolidation analyzes (combined groundwater flow with soil stress analyzes).

In case you have **groundflow_total_pressure_limit** set to 0 and the total pressure is 0, then Tochnog assumes that there is no water so the consolidation part in the equations will also be skipped. In case you have **groundflow_total_pressure_limit** set to a high positive value this will not be done, so the consolidation part will also be used in case the total pressure is 0 (or positive).

3.6 Wave equation

$$\frac{\partial \dot{s}}{\partial t} = c^2 \left(\frac{\partial^2 s}{\partial x_1^2} + \frac{\partial^2 s}{\partial x_2^2} + \frac{\partial^2 s}{\partial x_3^2} \right)$$
$$\frac{\partial s}{\partial t} = \dot{s}$$

The primary dof's are the **wave_scalar** s and its first time derivative **wave_fscalar** \dot{s} (as TOCHNOG only solves first order in time equations, the first time derivative of s also becomes primary dof in order to turn this second order in time equation into a set of first order in time equations). Further notation: x space coordinate, t time and c speed of sound.

3.7 Probabilistic distributions

The section summarises mathematical formulation of the so-called random finite element method, as described, e.g. in [6].

Distribution of a random variable (e.g., C) is controlled by these basic parameters: parameters of the statistical distribution (typically mean value μ_C and standard deviation σ_C) and so-called correlation length θ_C that controls spatial variability of variable C .

Two probabilistic distributions are available in Tochnog: normal distribution and log-normal distribution. Probability function $P(C)$ of normal distribution is defined as:

$$P(C) = \frac{1}{\sigma_C \sqrt{2\pi}} \exp \left[-\frac{(C - \mu_C)^2}{2\sigma_C^2} \right] \quad (18)$$

where μ_C is a mean value and σ_C is standard deviation. Probability function $P(C)$ of log-normal distribution is defined as:

$$P(C) = \frac{1}{C \sigma_{\ln C} \sqrt{2\pi}} \exp \left[-\frac{(\ln C - \mu_{\ln C})^2}{2\sigma_{\ln C}^2} \right] \quad (19)$$

Quantities $\mu_{\ln C}$ and $\sigma_{\ln C}$ may be calculated from μ_C and σ_C using

$$\sigma_{\ln C} = \sqrt{\ln \left[1 + \left(\frac{\sigma_C}{\mu_C} \right)^2 \right]} \quad \mu_{\ln C} = \ln \mu_C - \frac{1}{2} \sigma_{\ln C}^2 \quad (20)$$

3.7.1 Generation of random field

A number of different techniques to generate random fields is available (see, e.g., [5]). In this following, the most simple method based on Cholesky decomposition of the correlation matrix.

First, vector \mathbf{X} of statistically independent random numbers x_1, x_2, \dots, x_n (where n is number of elements in the FE mesh) with a standard normal distribution (i.e., with probability function of Eq. (18) with $\mu_C = 0$ and $\sigma_C = 1$) is generated.

A correlation matrix \mathbf{K} , which represents the correlation coefficient between each of the element used in the finite element analysis, is assembled. The correlation matrix \mathbf{K} has the following form:

$$\mathbf{K} = \begin{bmatrix} 1 & \rho_{12} & \dots & \rho_{1n} \\ \rho_{21} & 1 & \dots & \rho_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{n1} & \rho_{n2} & \dots & 1 \end{bmatrix} \quad (21)$$

where ρ_{ij} is the correlation coefficient between elements i and j , calculated using Markov function:

$$\rho_{ij} = \exp \left[-\frac{2x_{ij}}{\theta_C} \right] \quad (22)$$

where x_{ij} is absolute distance between elements i and j (distance between centers of gravity of elements i and j). For anisotropic case Eq. (22) reads

$$\rho_{ij} = \exp \left[-2 \sqrt{\left(\frac{\tau_{xij}}{\theta_{Cx}} \right)^2 + \left(\frac{\tau_{yij}}{\theta_{Cy}} \right)^2 + \left(\frac{\tau_{zij}}{\theta_{Cz}} \right)^2} \right] \quad (23)$$

where θ_{Cx} is a correlation coefficient in direction of x -axis and τ_{xij} is a distance between two elements i and j in x direction. The same notation applies for y and z directions.

The matrix \mathbf{K} is positive definite and hence, the standard Cholesky decomposition algorithm can be used to factor the matrix into upper and lower triangular forms, \mathbf{S} and \mathbf{S}^T , respectively:

$$\mathbf{S}^T \mathbf{S} = \mathbf{K} \quad (24)$$

The vector of correlated random variables \mathbf{G} (i.e., G_1, G_2, \dots, G_n , where G_i specifies the random component of variable C in element i) is calculated by

$$\mathbf{G} = \mathbf{S}^T \mathbf{X} \quad (25)$$

Vector \mathbf{X} is generated as described above.

Finally, value of the variable C is assigned to each element (C_i) by the following transformation:

- for normally distributed variable C :

$$C_i = \mu_C + \sigma_{CA} G_i \quad (26)$$

where σ_{CA} is calculated from σ_C as described in the following section.

- for log-normally distributed variable C :

$$C_i = \exp(\mu_{\ln C} + \sigma_{\ln CA} G_i) \quad (27)$$

where $\mu_{\ln C}$ is calculated by Eq. (20)b using $\sigma_{\ln CA}$ instead of $\sigma_{\ln C}$; $\sigma_{\ln CA}$ is calculated from $\sigma_{\ln C}$ as described in the following section.

3.7.2 Local averaging

The input parameters of C that relate to the mean, standard deviation and spatial correlation length are assumed to be defined at the point level. Due to the finite size of each finite element, point statistical distribution must be averaged over the element. This results in reduced $\sigma_{\ln C}$ in the case of log-normal distribution and reduced σ_C in the case of normal distribution. $\mu_{\ln C}$ in the first case and μ_C in the second case remain unaffected.

The locally-averaged standard deviations ($\sigma_{\ln CA}$, σ_{CA}), which are used in Eqns. (26, 27), are calculated from their point values using

$$\sigma_{\ln CA}^2 = \gamma \sigma_{\ln C}^2 \quad \sigma_{CA}^2 = \gamma \sigma_C^2 \quad (28)$$

where γ is the variance reduction factor calculated by integration of the Markov function (22). In 1D for a finite element of side length $\alpha\theta_C$

$$\gamma = \frac{2}{(\alpha\theta_C)^2} \int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C} \sqrt{x^2}\right) (\alpha\theta_C - x) dx \quad (29)$$

In 2D for square finite element of side length $\alpha\theta_C$

$$\gamma = \frac{4}{(\alpha\theta_C)^4} \int_0^{\alpha\theta_C} \int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C} \sqrt{x^2 + y^2}\right) (\alpha\theta_C - x)(\alpha\theta_C - y) dx dy \quad (30)$$

In 3D for hexahedral finite element of side length $\alpha\theta_C$

$$\gamma = \frac{8}{(\alpha\theta_C)^6} \int_0^{\alpha\theta_C} \int_0^{\alpha\theta_C} \int_0^{\alpha\theta_C} \exp\left(-\frac{2}{\theta_C} \sqrt{x^2 + y^2 + z^2}\right) (\alpha\theta_C - x)(\alpha\theta_C - y)(\alpha\theta_C - z) dx dy dz \quad (31)$$

For the anisotropic case in 2D:

$$\gamma = \frac{4}{l^4} \int_0^l \int_0^l \exp\left[-2\sqrt{\left(\frac{x}{\theta_{Cx}}\right)^2 + \left(\frac{y}{\theta_{Cy}}\right)^2}\right] (l-x)(l-y) dx dy \quad (32)$$

and for the anisotropic case in 3D:

$$\gamma = \frac{8}{l^6} \int_0^l \int_0^l \int_0^l \exp \left[-2 \sqrt{\left(\frac{x}{\theta_{Cx}} \right)^2 + \left(\frac{y}{\theta_{Cy}} \right)^2 + \left(\frac{z}{\theta_{Cz}} \right)^2} \right] (l-x)(l-y)(l-z) dx dy dz \quad (33)$$

In order to calculate the variance reduction due to local averaging correctly, all elements in the mesh should be of the same size and all elements should be regular squares. If irregular elements are used, exact value of γ is in Tochnog approximated by calculation of γ for an equivalent square element using Eq. (31) with area equal to an average area of all elements in the mesh.

The approximate value of γ requires that you use as much as possible elements of the same size and shape in the complete calculation domain.

3.7.3 Monte Carlo simulations

The most simple but very powerful technique to solve the probabilistic problem is a Monte Carlo technique. The same problem is solved many times, each time with different fields of random variables generated according to prescribed parameters.

The whole problem is solved in the following steps:

1. Generate random fields according to Sec. 3.7.1 using **control_distribute** command as many times as many variables are treated as random. In principle, any variable can be related as random. For example material parameters, dof's (e.g., history variables), etc.
2. Solve the problem using finite element method. Collect required results of each Monte Carlo realisation into an output file. The user can prescribe any result to be collected into an output file using **control_repeat_save** command (e.g., **time_current**, final displacement of a selected point, etc.).
3. Repeat items 1. and 2. m -times, where m is a prescribed number of Monte Carlo realisations. m value is specified in Tochnog input file using **control_repeat** command.
4. Evaluate results statistically. More complex statistical evaluation is done by the user, calculation of mean value and standard deviation can be done in Tochnog using **control_repeat_save_calculate** command.

3.7.4 Input data records

A typical piece of input file could be like this:

```
print_group_data ... (print in the gid files distributed group data so that you get a
plot of it)
...
control_distribute 10 ... (distribute something with correlation in space)
control_distribute_parameters 10 ...
control_distribute_correlation_length 10 ...
control_distribute 20 ... (distribute something else without correlation in space)
control_distribute_parameters 20 ...
...
control_timestep 30 ... (do timesteps)
control_timestep_iterations_automatic 30 ... (with automatic timestepping)
```

```

control_timestep_iterations_automatic_stop 30 -continue (don't abort the cal-
ulation if the minimum step size is reached, e.g. in a stability calculation)
...
control_print_data_versus_data 40 ... (save data for repeats in a dvd file)
...
control_repeat 50 100 10 (jump 100 times back to control index 10)
control_repeat_save 50 ... (select results to be saved for each repeat)
control_repeat_save_calculate 50 -yes (perform statistical analysis on saved results)
...
control_print_gid 100 -yes
control_print 100 -repeat_save_result -repeat_save_calculate_result
...

```

4 Input file, general remarks

The input is free format. Comments are enclosed between (), e.g. (this is comment only); a comma , is not allowed inside comments. The input should consist of an initialization part and a data part, separated by **end_initia** and ended by **end_data**

```
initialization
...
initialization
end_initia
data_item index data_values
...
data_item index data_values
end_data
```

Bold printed data in this manual can be used literally. *Italic* printed data is only symbolic (it represents a number or a word).

5 Input file, initialization part

The initialization part contains initialization records and an **end_initia** record

```
initialization
...
initialization
end_initia
```

The example below initializes a solid material

```
echo -yes
number_of_space_dimensions 2
materi_velocity
materi_strain_total
materi_stress
end_initia
```

The **echo** (always the first record), **number_of_space_dimensions** (always the second record), and **end_initia** record should be supplied always. Use **echo -yes** to echo the input and **echo -no** to not echo the input. Use **number_of_space_dimensions 1** for 1D problems, etc.. The records **materi_velocity**, **materi_strain_total** and **materi_stress** create a velocity, strain and stress field in the entire domain. In the following sections, all possible *initialization* records are discussed. Most of these records create an doffield, a physical field like a temperature field or a strain field, over the computational domain.

5.1 *echo switch* (first record of initialization part)

If *switch* is **-yes** the input will be echoed. If *switch* is **-no** the input will not be echoed. This needs to be the first record.

5.2 **number_of_space_dimensions** *number_of_space_dimensions* (second record of initialization part)

Set *number_of_space_dimensions* to 1 in 1D, etc.. This needs to be the second record.

5.3 **derivatives** (third record of initialization part, if specified)

If this record is included, the time derivative and the space derivatives will be stored in the **node_dof** records. This is only required for a limited number of models. The model description will specify if this **derivatives** initialization is needed.

5.4 **beam_rotation**

The beam rotations ϕ_x , ϕ_y and ϕ_z are added to the **node_dof** records.

Please notice that always all three rotations are included. Typically for a 2D calculation you may want to fix the ϕ_x and ϕ_y to 0, by using a **bounda_dof** record.

5.5 condif_temperature

The temperature T is added to the **node_dof** records.

5.6 groundflow_pressure

The pressure p is added to the **node_dof** records.

5.7 groundflow_pressure_gradient

The gradient of the hydraulic pressure $\frac{dh}{dx} \frac{dh}{dy} \frac{dh}{dz}$ is added to the **node_dof** records.

5.8 groundflow_saturation

The groundflow saturation S is added to the **node_dof** records.

5.9 groundflow_velocity

The ground water flow velocity v_i^g is added to the **node_dof** records.

5.10 materi_damage

The damage d is added to the **node_dof** records. Also **materi_velocity** and **materi_strain_total** should be initialized.

5.11 materi_acceleration

The accelerations a_i are added to the **node_dof** records.

5.12 materi_displacement

The displacements u, v, w are added to the **node_dof** records. If **materi_displacement** is initialized, then equations like the convection and diffusion of heat equation or the ground water flow equation are evaluated over the deformed volume, which is the sum of the nodal coordinates plus its displacements. Also if **materi_displacement** is initialized, the total Lagrange model will be used in stress analysis.

Condition: also **materi_velocity** should be initialized because the displacement follows from integration of the velocity.

5.13 **materi_displacement_relative**

Displacement relative to a previous point in the calculation. These are the current displacements minus the displacements before these were changed with timesteps in **control_timestep** or a displacement reset in **control_reset_dof**.

By example, this option comes handy when you want to understand the extra displacements caused by the last timesteps.

5.14 **materi_history_variable** *number_of_variables*

Generic history variables which can e.g. be used in some user supplied routines or otherwise.

5.15 **materi_maxwell_stress** *number_of_chains*

Maxwell stress $\sigma_{11}^m \sigma_{12}^m \sigma_{13}^m \sigma_{22}^m \sigma_{23}^m \sigma_{33}^m$ is added to the **node_dof** records. The parameter *number_of_chains* should match data item **group_materi_maxwell_chains**. The number of maxwell stresses is $6 * \text{number_of_chains}$.

5.16 **materi_plasti_camclay_history**

The history variables e_0 and p_0 for the camclay plasticity models are added to the **node_dof** records.

5.17 **materi_plasti_cap1_history**

The history variable p_c for the cap1 plasticity models is added to the **node_dof** records.

5.18 **materi_plasti_diprisco_history** *number_of_history_variables*

The history variable di Prisco plasticity models are added to the **node_dof** records. For the **group_materi_plasti_diprisco** model you need to set *number_of_history_variables* to 11. For the **group_materi_plasti_diprisco_density** model you need to set *number_of_history_variables* to 12.

5.19 **materi_plasti_f**

The plastic yield rule f is added to the **node_dof** records. This should only be used for elasto-plastic calculations, and not for visco-plastic calculations.

5.20 **materi_plasti_f_nonlocal**

The nonlocal plastic yield rule fn is added to the **node_dof** records. See also: **nonlocal**.

5.21 `materi_plasti_generalised_non_associate_cam_clay_for_bonded_soils_history`

The history variables for the Generalised Non Associate Cam Clay for Bonded Soils plasticity model are added to the **node_dof** records.

5.22 `materi_plasti_hardsoil_history`

The history variable $abs(p)$ for the hardsoil plasticity model is added to the **node_dof** records. It contains the maximum pressure history.

5.23 `materi_plasti_hypo_history` *number_of_history_variables*

The history variables for the hypo-plasticity models are added to the **node_dof** records. You need to set *number_of_hypo_history_variables* to at least to 4, or for the **group_materi_plasti_masin** model i.c.w. **group_materi_plasti_masin_structure** to at least to 5.

The first history variable contains the void ratio, and should be initialized by initially specifying **node_dof** records. The second history variable will be filled with the time step size of the hypoplastic substepping scheme. The third history variable will be filled with the mobilized friction angle; this is meant for postprocessing only. The fourth history variable will be filled with the a measure of the effective stiffness following from the hypoplasticity law ($\sqrt{M_{ijkl}M_{ijkl}}$); this is meant for postprocessing only. The fifth history variable, for the masin law, will be filled with the structure variable s , and should be initialized by initially specifying **node_dof** records. The sixth history variable, will be filled with the *OCR* value, and is only meant for printing and plotting, thus should not be initialized by initially specifying **node_dof** records (you need to set *number_of_history_variables* at least to 6). The seventh history variable will be filled with the density index $I_d = \frac{ec-e}{ec-ed}$, and is only meant for printing and plotting, thus should not be initialized by initially specifying **node_dof** records (you need to set *number_of_history_variables* at least to 7, and it is only available i.c.w. **group_materi_plasti_hypo_wolffersdorff**).

5.24 `materi_plasti_kappa`

The size of the plastic strain κ is added to the **node_dof** records. See the theory section.

5.25 `materi_plasti_kappa_shear`

The size of the shear part of the plastic strain κ^{shear} is added to the **node_dof** records. See the theory section.

5.26 `materi_plasti_laminate` *number_of_laminates*

This initialises the number of laminates for the multilaminate plasticity model. At most 6 is allowed for *number_of_laminates*.

5.27 materi_plasti_phimob

The mobilized friction angle ϕ_{mob} is added to the **node_dof** records. It is defined as the angle, in radians, for which the yield function

$$f = 0.5(\sigma_2 - \sigma_0) + 0.5(\sigma_2 + \sigma_0) * \sin(\phi_{mob}) - c \cos(\phi_{mob})$$

becomes zero. This is available for mohr-coulomb and matsuoka-nakai plasticity only. Please realise that in regions with substantial cohesion the mobilized friction angle ϕ_{mob} can exceed the friction angle ϕ from the plasticity law. In case of zero cohesion, or cohesion small relative to the stresses, yield is reached if the ϕ_{mob} reaches the friction angle ϕ . The definition above can give either negative or positive values for ϕ_{mob} ; negative values simply indicate that the stress state is far away from yielding.

5.28 materi_plasti_rho

The plastic kinematic hardening vector $\rho_{11} \rho_{12} \rho_{13} \rho_{22} \rho_{23} \rho_{33}$ is added to the **node_dof** records. See also **group_materi_plasti_kinematic_hardening**.

5.29 materi_strain_energy

The material strain energy $0.5\sigma_{ij}\epsilon_{ij}^{elas}$ is added to the **node_dof** records. You can print or plot it to see where energy is stored after loading. Also **materi_stress** and **materi_strain_elasti** should be initialised.

5.30 materi_strain_elasti

The elastic strain ϵ_{kl}^{elas} is added to the **node_dof** records. See also: **materi_strain_total**.

5.31 materi_strain_intergranular

The intergranular strain S_{ij} is added to the **node_dof** records. This can be used by hypoplasticity laws, see the theory section.

5.32 materi_strain_plasti

The plastic strain ϵ_{kl}^{plas} is added to the **node_dof** records. See also: **materi_strain_total**.

5.33 materi_strain_plasti_camclay

The plastic strain ϵ_{kl}^{plas} specifically for the camclay model is added to the **node_dof** records. See also: **materi_strain_plasti**.

5.34 materi_strain_plasti_cap

The plastic strain ϵ_{kl}^{plas} specifically for cap models is added to the **node_dof** records. See also: **materi_strain_plasti**.

5.35 `materi_strain_plasti_compression`

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the compression model is added to the **node.dof** records. See also: **materi_strain_plasti**.

5.36 `materi_strain_plasti_diprisco`

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the diprisco model is added to the **node.dof** records. See also: **materi_strain_plasti**.

5.37 `materi_strain_plasti_generalised_non_associate_cam_clay_for_bonded_soils`

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the generalised non associate cam clay for bonded soils model is added to the **node.dof** records. See also: **materi_strain_plasti**.

5.38 `materi_strain_plasti_druckprag`

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the drucker-prager model is added to the **node.dof** records. See also: **materi_strain_plasti**.

5.39 `materi_strain_plasti_hardsoil`

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the hardsoil model is added to the **node.dof** records. See also: **materi_strain_plasti**.

5.40 `materi_strain_plasti_laminate_mohr_coul`

This record initialises for the laminates **materi_strain_plasti_laminate0_mohr_coul** , **materi_strain_plasti_laminate1_mohr_coul** , etc up to **materi_strain_plasti_laminate_mohr_coul**.

The **materi_strain_plasti_laminate0_mohr_coul** is the mohr-coulomb plastic strain specifically for laminate 0,

the **materi_strain_plasti_laminate1_mohr_coul** is the mohr-coulomb plastic strain specifically for laminate 1, etc.

The **materi_strain_plasti_laminate_mohr_coul** is the mohr-coulomb plastic strain for all laminates together,

See also: **materi_strain_plasti**.

5.41 `materi_strain_plasti_laminate_tension`

This record initialises for the laminates **materi_strain_plasti_laminate0_tension** , **materi_strain_plasti_laminate1_tension** , etc up to **materi_strain_plasti_laminate_tension** ,

The **materi_strain_plasti_laminate0_tension** is the tension cutoff plastic strain specifically for laminate 0,

the **materi_strain_plasti_laminate1_tension** is the tension cutoff plastic strain specifically for

laminate 1, etc.

The **materi_strain_plasti_laminate_tension** is the tension cutoff plastic strain for all laminates together,

See also: **materi_strain_plasti**.

5.42 **materi_strain_plasti_matsuoka_nakai**

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the matsuokanakai model is added to the **node_dof** records.

See also: **materi_strain_plasti**.

5.43 **materi_strain_plasti_mohr_coul**

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the mohr_coulomb models is added to the **node_dof** records. See also: **materi_strain_plasti**.

5.44 **materi_strain_plasti_tension**

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the tension model is added to the **node_dof** records. See also: **materi_strain_plasti**.

5.45 **materi_strain_plasti_vonmises**

The plastic strain $\epsilon_{kl}^{\text{plas}}$ specifically for the von-mises model is added to the **node_dof** records. See also: **materi_strain_plasti**.

5.46 **materi_strain_total**

The total strain ϵ_{kl} is added to the **node_dof** records. All strains are time integrals of the strain rates for a specific material particle which happens to be present in the node.

5.47 **materi_strain_total_kappa**

The maximum strain size is added to the **node_dof** records.

5.48 **materi_strain_total_compression_kappa**

The maximum principal compression total strain as occurred in history is added to the **node_dof** records.

5.49 **materi_strain_total_shear_kappa**

The maximum size of the deviatoric part of the total strain as occurred in history is added to the **node_dof** records.

5.50 **materi_strain_total_tension_kappa**

The maximum principal tensional total strain as occurred in history is added to the **node_dof** records.

5.51 **materi_stress**

The stresses σ_{11} σ_{12} σ_{13} σ_{22} σ_{23} σ_{33} are added to the **node_dof** records.

5.52 **materi_stress_pressure_history**

The maximum of the absolute value of the pressure which occurs over time is added to the **node_dof** records. See also **group_materi_elasti_stress_pressure_history_factor** in the data part.

5.53 **materi_velocity**

The velocities v_i are added to the **node_dof** records.

5.54 **materi_velocity_integrated**

The integrated velocities vi_i are added to the **node_dof** records. The integration of nodal velocities in fact results in displacements. But asking for these integrated velocities doesn't activate automatically that the calculation is done over the total deformed volume (as is the case when you initialize **materi_displacement**), and not automatically a total Lagrange model is used in stress analysis.

5.55 **materi_void_fraction**

The material void fraction f^* is added to the **node_dof** records. This is required for the **group_materi_plasti.g** model.

5.56 **materi_work**

The material second order work $\dot{\sigma}_{ij}\dot{\epsilon}_{ij}$ is added to the **node_dof** records. You can print or plot it to see where material instabilities are present.

5.57 **mrangle** *maximum_range_length*

Sets the maximum length of ranges **-ra ... -ra**.

5.58 **mstring** *maximum_number_of_strings*

Sets the maximum number of strings in a define block.

5.59 truss_bond_slip

The truss bond slip displacements s_x , s_y and s_z are added to the **node_dof** records. See the theory section for a discussion on the bond slip between trusses and isoparametric elements.

5.60 wave_scalar

Scalar in wave equation is **node_dof** records. Condition: also **wave_fscalar** should be initialized.

5.61 wave_fscalar

The first time derivative in the wave equation is added to the **node_dof** records. Condition: also **wave_scalar** should be initialized.

5.62 end_initia (last record of initialization part)

6 Input file, data part, introduction

Data items in the data part are used to control the calculation, select required output, give dof's initial values, etc.. Note that an **end_data** record is needed.

```
data_item index data_values
...
data_item index data_values
end_data
```

Consider the following example

```
element 0 -tria3 0 1 2
element 1 -tria3 1 2 3
node 0 0. 0.
node 1 1. 0.
node 2 0. 1.
node 3 1. 1.
...
end_data
```

Note that the data items **element** and **node** are indexed. In fact most data items need to be indexed. Indexing starts at 0 (all numbering in TOCHNOG starts at 0). Indices need not strictly be sequential (e.g. only the indices 1,2 and 5 of a data item may be specified).

The following sections first treat some extras that can be used in the data part. After that, all possible data items are specified.

Arithmetic blocks

You also can use the arithmetic expressions **plus**, **minus**, **multiply** and **divide**. We show some examples:

```
(make A equal to 4.1)
start_arithmetic
A 1.1 plus 3
end_arithmetic
...
(make B equal to 3.2)
start_arithmetic
B 3.2
end_arithmetic
...
(make C equal to 7.3)
start_arithmetic
C A plus B
end_arithmetic
...
(make D equal to 14.6)
start_arithmetic
```

```
D A plus B multiply 2.
end_arithmetic
```

Expressions will be evaluated from left to right. Words from define blocks will *not* be recognized in arithmetic blocks.

Automatic counting: the counters

The words **counter_a**, **counter_b**, **counter_c** and **counter_d** are reserved words in the data part. If they are found, they will be substituted by their integer value. After its value is substituted, the counter will be incremented by 1. Initially the value for counters is 0. The example below shows a typical application.

```
start_define
left_edge geometry_line counter_a
end_define
start_define
right_edge geometry_line counter_a
end_define
...
left_edge 0. 0. 0. 10. 1.e-4
right_edge 2. 0. 2. 10. 1.e-4
...
bounda_dof 1 -left_edge -velx
bounda_time 1 0.
bounda_dof 2 -right_edge -velx
bounda_time 2 1.3
...
```

Notice that we automatically give the geometry lines a unique number in this way; the unique number is not really of interest in the remainder of the input file, so the application of a counter is convenient.

Finally, also the words **counter_a_apply**, **counter_b_apply**, **counter_c_apply** and **counter_d_apply** are available. They will be substituted by the current value of the counters, without that the counters are incremented.

Conditional blocks

Parts of the input file can be processed conditionally within **start_if ... end_if** blocks. This is illustrated below with an example:

Example:

```
start_define
do_complete_calculation true
end_define
...
start_if do_complete_calculation
...
```



```

end_if
...

```

The part in the **start_if ... end_if** block is only done if **do_complete_calculation** is set to **true**, like in the example. If **do_complete_calculation** is set to **false** that part will be skipped. You also can use **start_if_not ... end_if_not** blocks, so that actions are NOT taken if the defined variable is set to true.

Control indices

All possible data items are defined in the following sections. It only makes sense to specify some of the data items before the calculation; the other data items are only meant to be printed after the calculation. The example below specifies a 1D temperature calculation.

```

echo -no
number_of_space_dimensions 1
condif_temperature
end_initia

node 1 0
node 2 1
node 3 2

element 1 -bar2 1 2
element 2 -bar2 2 3

bounda_dof 0 1 -temp
bounda_time 0 0.0 0. 1. 1. 100. 1.
bounda_dof 1 3 -temp
bounda_time 1 0.0 0.0 100.0 0.

group_type 0 -condif
group_condif_density 0 1.0
group_condif_capacity 0 0.1
group_condif_conductivity 0 0.1
group_condif_flow 0 0.

control_timestep 0 0.1 10.0
control_print 0 -time_current -node_dof
control_print_database 1 -separate_index
control_timestep 2 0.2 10.0
control_print 2 -time_current -node_dof

end_data

```

Note how the indices of control items like **control_timestep** and **control_print** are used to control the sequence of events. First, (*index=0*) time steps of size 0.1 are taken and for each time step results are printed. Then (*index=1*) the database is printed which can serve as a point of restart. Finally (*index=2*) time steps of size 0.2 are taken and for each time step results are printed.

Define blocks

You can define a word to represent a set of strings. For each word defined, you need to specify a **start_define** ... **end_define** block. Within the block, you first specify the word, and then you specify the set of strings. Later in the data part, you can use the defined words as the replacement of the set of strings.

Example:

```

start_define
velocity 1.34
end_define
start_define
left_edge geometry_line 1
end_define
...
left_edge 0. 0. 0. 10. 1.e-4
...
bounda_dof 1 -left_edge -velx
bounda_time 1 0. 0. 100. velocity
...

```

The words **plus**, **minus**, **multiply** and **divide** as used in arithmetic blocks are prohibited in define blocks.

Include files

You can use **include** *filename* in the data part, to request that the file with name *filename* is included. This is handy to include often used data parts, or include a mesh generated by a pre-processor, etc.

The included file itself is not allowed to have an **include** in the data part.

The included file should not contain comments (...). The included file needs to be ended with an **end_data**. On some MS windows computers two **end_data** records are needed, so try that in case of trouble. On MS windows 32 bit computers include is not available.

Numbering of values in records

The numbering of values in records is illustrated by **node_dof** records. Look at the following piece of input file

```

...
number_of_space_dimensions 2
materi_velocity
materi_stress
end_initia
...
node_dof 1 0.0 0.0 -1.0 0.0 0.0 -1.0 0.0 -1.0
node_dof 2 0.0 0.0 -1.0 0.0 0.0 -1.0 0.0 -1.0
...
end_data

```

Here **node_dof** records 1 and 2 are initialized. The initial velocities are 0, and for the initial stresses we use $\sigma_{xx} = -1$, $\sigma_{yy} = -1$ and $\sigma_{zz} = -1$. The total list of dof's in the **node_dof** record is **-velx**, **-vely**, **-sigxx**, **-sigxy**, **-sigxz**, **-sigyy**, **-sigyz** and **-sigzz**.

We refer to **-velx** as the 0'th value in the **node_dof** record, **-vely** as the 1'th value, etc. So printing the history of the **-sigxx** stress of **node_dof** record 1 is obtained by this:

```
...
control_timestep 10 ...
control_print_history 10 -node_dof 1 2
...
end_data
```

where the number 2 refers to the **-sigxx** stress. See also the definition of the **control_print_history** record for this. As an alternative, sometimes you can use names instead of numbers, for example here:

```
...
control_timestep 10 ...
control_print_history 10 -node_dof 1 -sigxx
...
end_data
```

Ranges

Ranges are general input formats used for indices and data values. Possible ranges are illustrated by the following examples

```
-all
-ra 12 32 44 -ra
-ra -from 5 -to 16 -ra
-ra -from 5 -to 25 -step 2 -ra
```

The **-all** range is not available for indices.

The data values for a data item can be specified as a range if this is allowed for in the description of the data item. All words in the data part (or part of an index) need to be preceeded with a 'tic' (-). In the example the **node_dof** records 1 to 100 are initialized

```
node_dof -ra -from 1 -to 100 -ra 1. 0. 0.
```

Types of dof's

Some of the dof's are principal dof's: these are **materi_velocity**, **condif.temperature**, **ground-flow_pressure**, **wave_fscalar**. These are the dof's which are solved by the equilibrium equations (conservation laws).

The other dof's, like **materi_stress** and so, follow from these principal dof's (strains follow from displacement derivatives, stresses follow from strains by material laws, etc.).

Furthermore, for all the dof's we have primary values, which are the dof's themselves, and derived dof's, which are the space and time derivatives of the primary dof's.

7 Input file, data part, data records

7.1 **area_element_group** *index geometry_entity_item geometry_entity_index element_group*

This record is used to generate **element_group** records. Each element, all of whose nodes are part of the *geometry_item*, will get an **element_group** record with value *element_group*. Please realise that the geometry entity can be a two-dimensional area, a volume, etc.

This option comes handy whenever a part of the domain gets some specific element data. For example, this would be the case if different areas in the structure have different material properties like stiffness, etc.

Beware: any directly specified **element_group** records will be overwritten.

Attention: this **area_element_group** will be evaluated each time the mesh is changed in some way. Then the **area_element_group** information will be used again to generate **element_group** records for the changed mesh.

We show here two ways to get different element data in different regions: Both ways give elements with young 1.2 from x=0 to x=1, and elements with young 3.3 from x=1 to x=2.

First way:

```
..
node 1 0.
node 2 1.
node 3 2.
element 1 -bar2 1 2
element 2 -bar2 2 3
element_group 1 0
element_group 2 1
..
group_type 0 -materi
group_materi_elasti_young 0 1.2
group_type 1 -materi
group_materi_elasti_young 1 3.3
..
control_mesh_refine_globally 10 -h_refinement
..
```

Second way:

```
..
node 1 0.
node 2 1.
node 3 2.
element 1 -bar2 1 2
element 2 -bar2 2 3
..
group_type 0 -materi
group_materi_elasti_young 0 1.2
```

```

group_type 1 -materi
group_materi_elasti_young 1 3.3
..
geometry_line 1 0. 1. 1.e-4
geometry_line 2 1. 2. 1.e-4
area_element_group 1 -geometry_line 1 0
area_element_group 2 -geometry_line 2 1
..

```

See also `area_element_group_method`, `area_element_group_sequence_element_group` etc.

7.2 `area_element_group_element` *index name*

With `area_element_group_element` you select the name of the elements for which the `area_element_group` will be used; if this `area_element_group_element` is not specified then all elements will be used.

7.3 `area_element_group_interface` *index switch*

If *switch* is set to **-yes** the `area_element_group` record with the same index will also be used for interface elements. If *switch* is set to **-no** the `area_element_group` record with the same index will not be used for interface elements. Default *switch* is set to **-no**.

7.4 `area_element_group_method` *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding `area_element_group` is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding `area_element_group` is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

7.5 `area_element_group_node` *index node_0 node_1 ... element_group*

Similar to `area_element_group`. Now, however, directly the global node numbers are specified.

7.6 `area_element_group_sequence` *index element_0 element_1 ...*

See `area_element_group_sequence_element_group`.

7.7 `area_element_group_sequence_element` *index name*

See `area_element_group_sequence_element_group`.

7.8 `area_element_group_sequence_element_group` *index group_0 group_1 ...*

General description

This option works more or less the same as the **area_element_group** option. Read that description first.

With this option however, you can specify what the element group numbers of an area (geometry), or set of element numbers, will be in time. This allows for an easy modeling of change of material models.

This option works in combination with the **area_element_group_sequence_*** records (with the same index).

Selection of elements for which the element group changes over time

With **area_element_group_sequence_geometry** you select the area (geometry) for which the time sequence of group numbers should be used.

With **area_element_group_sequence** you select the elements for which the time sequence of group numbers should be used.

You can use both **area_element_group_sequence_geometry** and **area_element_group_sequence** to select a combination of elements in a geometry and directly specified element numbers. As a completely separate option do not use any of **area_element_group_sequence_geometry** and **area_element_group_sequence** at all. Then at a time point *time_i* the elements which have group number *group_(i-1)* will get new group number *group_i*. So the previous group number of elements is used to set the current group number of elements (and geometries are not used to change the group numbers).

With **area_element_group_sequence_element** you select the name of the elements for which the sequence of time versus group will be used; if this **area_element_group_sequence_element** is not specified then all elements will be used.

Specification of new element group numbers in time

With **area_element_group_sequence.time** and **area_element_group_sequence.element_group** you select time points at which groups should become active; for example, group_0 becomes active at time_0 etc.

Remarks

Remark 1: If you want the stresses, strains, etc. to be reset to 0. when the element group changes, then use a **control_reset_geometry** record for that.

Remark 2: It is more convenient and clear to use the **start_define end_define** option to define the geometries.

Examples

Example:

```
area_element_group_sequence_geometry 0 -geometry_brick 1
area_element_group_sequence_element 0 -hex8
area_element_group_sequence.time 0 0. 2. 3.
area_element_group_sequence.element_group 0 1 5 4

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
```

```
...
control_reset_geometry 10 -geometry_brick 1
...
```

In the selected geometry element group 1 will be used starting from time 0 for elements **-hex8**. Starting from time 2 element group 5 will be used, etc. Same example, now with defines however:

```
start_define
soil_empty_wall geometry_brick 1
end_define
...

area_element_group_sequence_geometry 0 -soil_empty_wall
area_element_group_sequence_element 0 -hex8
area_element_group_sequence_time 0 0. 2. 3.
area_element_group_sequence_element_group 0 1 5 4

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
...
control_reset_geometry 10 -soil_empty_wall
...
```

Now an example of the separate option:

```
area_element_group_sequence_time 0 0. 2. 3.
area_element_group_sequence_element_group 0 1 5 4

element_group 77 1
element_group 78 1

group_type 1 ...
...
group_type 5 ...
...
group_type 4 ...
```

At time 0. elements 77 and 78 have group number 1. At time 2. the elements with group number 1 get group number 5. At time 3. the elements with group number 5 get group number 4.

7.9 `area_element_group_sequence_geometry index geometry_entity_item geometry_entity_index`

See `area_element_group_sequence_element_group`.

7.10 **area_element_group_sequence_geometry_method** *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding **area_element_group_sequence_geometry** is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding **area_element_group_sequence_geometry** is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

7.11 **area_element_group_sequence_interface** *index switch*

If *switch* is set to **-yes** the **area_element_group_sequence_*** will be used for interface elements also. If *switch* is set to **-no** the **area_element_group_sequence_*** will not be used for interface elements. Default *switch* is set to **-no**.

7.12 **area_element_group_sequence_time** *index time_0 time_1 ...*

See **area_element_group_sequence_element_group**.

7.13 **area_element_group_dof** *index group_0 group_1 dof*

This option allows you to switch the **element_group** from *group_0* to *group_1* depending on the value of *dof*, which is one of the items of **dof_label** or **post_calcul_label**.

If the value is higher than *critical_dof_value* any **element_group** *group_0* is switched to *group_1*. If the group in an element is switched, the element becomes active again only after a time lap *time_lap*; in the time in between the element is empty.

Unknowns can optionally be set to 0 when an element group changes; use for the corresponding switch in **area_element_group_dof_reset** a **-yes**. For dof's that don't need to be reset you need to use a **-no**. If you specify the **area_element_group_dof_reset** a switch needs to be specified for each and every dof in **dof_label**. Unknowns are listed in **dof_label**.

As a typical application this option can be used to give an element other group properties if plasticity strains exceed a critical limit, by example in modeling propagation of cracks in concrete.

7.14 **area_element_group_dof_parameters** *index critical_dof_value time_lap*

See **area_element_group_dof**.

7.15 **area_element_group_dof_reset** *index switch_0 switch_1 ...*

See **area_element_group_dof**.

7.16 **area_node_dataitem** *index geometry_entity_item geometry_entity_index data_item_name*

This record is used to generate *data_item_name* records on all nodes located on the specified geometrical entity. The values for the *data_item_name* should be specified in the **area_node_dataitem_double** record for real precision values, or in the **area_node_dataitem_integer** record for integer values (or words).

7.17 `area_node_dataitem_double` *index value_0 value_1 ...*

See `area_node_dataitem`.

7.18 `area_node_dataitem_integer` *index value_0 value_1 ...*

See `area_node_dataitem`.

7.19 `bounda_alternate` *index bounda_index_0 bounda_index_1 ...*

This option takes care that between successive iterations only one of the specified **bounda_dof** is not used. By example if **bounda_dof** records with index 10, 20 and 30 are present in the input file, and you use **bounda_alternate 10 20 30** then in subsequent iterations the following index is not used: 10, 20, 30, 10, 20, 30, 10, ... etc.

This option comes handy to allow for very large calculations on a computer with limited memory. By putting alternating boundary conditions on velocities, pressures or temperatures the system of active equations to be solved in each iterations is only of a limited size. And then using enough iterations the solutions for all dof's can slowly converge to the actual coupled solution.

As example consider a large 3d calculation where displacements and hydraulic heads need to be solved:

```
solver_matrix_symmetric -yes
...
bounda_alternate 10 20 30 40
bounda_dof 10 -all -velx
bounda_dof 20 -all -vely
bounda_dof 30 -all -velz
bounda_dof 40 -all -pres
...
control_timestep 100 ..
control_timestep_iterations 100 20
```

The above **bounda_dof** records are additional to the normally present records, like fixing displacements at sides of the domain, boundary conditions on hydraulic pressure, etc. The **bounda_alternate** record instructs tochnog to subsequently neglect the record 10, 20, 30, 40, 10, ..., etc. When a record is neglected the corresponding solution field can be solved. By example in the first iteration the solution field for the x-displacement can be solved, while the y-displacement and z-displacement and hydraulic head are kept fixed. And thus the total system of equations is much smaller, approximately 4 times less dof's need to be solved by the pardiso solver, which in fact is the bottleneck in computer memory usage for very large calculations. Notice that we asked tochnog to use the symmetric equation solver, since the pressures and displacements are not used simultaneously, so we don't have the disadvantage of a non-symmetric matrix with displacement and pressure contributions.

As another example we use a classical staggered solution for displacements and water pressures:

```

solver_matrix_symmetric -yes
...
bounda_alternate 10 20
bounda_dof 10 -all -velx -vely -velz
bounda_dof 20 -all -pres
...
control_timestep 100 ..
control_timestep_iterations 100 20

```

You should not specify **bounda_time** records i.c.w. **bounda_dof** records which are used in **bounda_alternate**. The **bounda_time** records will not be used.

7.20 **bounda_baseline_correction** *time_start time_end*

If this record is specified baseline correction is performed after one of:

- reading SMC files with uncorrected accelerations in **bounda_dof** i.c.w. **bounda_time_smc**.
- direct specification of acceleration in **bounda_dof** i.c.w. **bounda_time**.

Such baseline correction is needed to suppress artificial drift in velocity signals following from the acceleration signal.

The correction actually is done by adding a parabolic acceleration signal to the specified accelerations, thus giving a corrected acceleration in time. The parabolic (second order) signal contains three constant coefficients. These are determined by demanding that the corrected acceleration signal leads to a minimal sum of squared velocities over the considered time interval.

This correction is done over the time interval from *time_start* up to *time_end*. Typically *time_start* *time_end* are the start time and the end time of the time interval in which you apply base excitation. You need to specify these times in units that you actually use in your Tochnog calculation (so not in the units of the SMC file).

If this **bounda_baseline_correction** is not specified the data will be used directly without a correction.

See also **bounda_baseline_correction_parameters**.

7.21 **bounda_baseline_correction_parameters** *index ...*

The parameters for the parabolic baseline correction are written in this record. In future calculations you can use the parameters yourself by setting this record in the input file; then the parameters will not be determined again by the baseline correction algorithm; the parameters in the specified record will be used instead.

7.22 **bounda_constant** *index switch*

This record can be used i.s.o. the **bounda_time** record. If *switch* is set to **-yes** the prescribed dofis kept constant. This is only available for velocities, pressures and temperatures. This is not available for time derivatives **ttemp**, **tpres** and **ttotal_pres**.

7.23 **bounda_dof** *index node_range dof_0 dof_1 ...*

States which dof's in which nodes get prescribed values by adjustment of the **node_dof** records. The item *node_range* represents a range of node numbers. In stead of a node range also, by example, **-geometry_line 1** can be used, indicating that the nodes on line 1 get the prescribed boundary values. The items *dof_0* etc. are one of the primary dof's listed at **dof_label**.

For a specific *index*, only one of **bounda_force** or **bounda_dof** can be specified (thus either Neumann conditions or Dirichlet conditions).

Example for discrete node forces in y-direction on the nodes on a line:

```
bounda_dof 0 -geometry_line 1 -vely  
bounda_time 0 0. 0. 1. 1. 100. 1.
```

Normally you only should specify boundary conditions on principal dof's (like velocity, temperature, etc.) and not on strain, stresses, etc.!

Specially for velocity (displacement) dof's, you can prescribe that nodes should not move in a direction normal to a plane. For this, specify **-veln** for *dof_0* to indicate that the normal velocity to a plane is 0. The normal direction should be given with **bounda_normal**; if however a geometrical entity is used to specify the nodes, you do not necessarily need to specify the **bounda_normal**, thus the normal from the geometrical entity is then used instead. The **bounda_time** record should not be specified (it is irrelevant). Internally in Tochnog a multi-point-constraint will be generated to accomplish this condition of zero velocity in normal direction.

Specially for velocity (displacement) dof's, you can prescribe a rotation around either the x-axis, y-axis or z-axis. In 1D you cannot use this record. In 2D you can only specify a rotation around the z-axis. In 3D you can specify each of the three axis. Example of an x-axis rotation of node 12 with angular velocity of 0.33 [degrees per unit time]:

```
bounda_dof 0 12 -rotation_x_axis  
bounda_time 0 0.33
```

For the rotation 0.33 the rotation vector points in the positive x-axis direction.

Specially for the groundflow phreatic head *h*, you can prescribe the physical pore pressure **-total_pressure** and Tochnog will automatically calculate the corresponding hydraulic head *h*. Also specially for the groundflow phreatic head *h*, you can prescribe the time rate of the physical pore pressure **-ttotal_pressure** and Tochnog will automatically calculate the corresponding hydraulic head *h*. Also specially for the groundflow phreatic head *h*, you can prescribe the time rate of the hydraulic head **-tpres**. Specially for the temperature you can prescribe the time rate of the temperature **-ttemp**.

As a special option you can specify also, by example, **-element_group 1** in stead of a node range. Then nodes of elements which have **element_group** set to 1 will get the prescribed boundary values.

As a special option you can specify also, by example, **-element_geometry 1** in stead of a node range. Then nodes of elements which have **element_geometry** set to 1 will get the prescribed boundary values.

As a special option you can specify also, by example, **-geometry_set 1** instead of a node range. Then nodes of elements which have any of the elements belonging to **geometry_set 1** will get the prescribed boundary values.

Notice: if several **bounda_dof** records act on a node, only the record with the highest index will be used.

See also: **bounda_time**, **bounda_sine**, **bounda_constant**, **bounda_dof_radial**, **bounda_dof_cylindrical**, **force_edge** and **force_volume**.

7.24 **bounda_dof_cylindrical** *index x_first y_first z_first x_second y_second z_second*

Specially for velocity (displacement) dof's, you can prescribe velocities cylindrical to a line specified with the point *x_first*, *y_first*, *z_first* and *x_second*, *y_second*, *z_second*; in 1D only *x* values should be specified, and in 2D only *x*, *y* values should be specified. Example:

```
bounda_dof 10 -ra -ldots -ra -velx -vely -velz
bounda_dof_cylindrical 10 1.23 3.43 5.12 1.23 3.43 15.12
bounda_time 10 0. 0. 1. 1. 100. 1.
```

The velocity increases linearly in size away from the specified line (at unit distance away from the line the velocity has size 1; you can scale it by the **bounda_time** record).

7.25 **bounda_dof_radial** *index x y z*

Specially for velocity (displacement) dof's, you can prescribe velocities radial to a specified point *x*, *y*, *z*; in 1D only *x* should be specified, and in 2D only *x*, *y* should be specified. Example:

```
bounda_dof 10 -ra -ldots -ra -velx -vely -velz
bounda_dof_radial 10 1.23 3.43 5.12
bounda_time 10 0. 0. 1. 1. 100. 1.
```

A radial velocity is prescribed on nodes in a specified range, relative to point 1.23, 3.43, 5.12 and with the time table given by **bounda_time**. The velocity increases linearly in size away from the specified point *x*, *y*, *z* (at unit distance away from the specified point *x*, *y*, *z* the velocity has size 1; you can scale it by the **bounda_time** record).

7.26 **bounda_factor** *index a₀ a₁ ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **bounda_time** records (with the same index). In this way, you can obtain coordinate dependent boundary conditions.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if $n=2$ the polynomial is $a_0 + a_1x + a_2y$ (specify 3 values). By example if $n=5$ the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2$ (specify 6 values). By example if $n=8$ the polynomial is $a_0 + a_1x + a_2x^2 + a_3y + a_4y^2 + a_5xy + a_6x^3 + a_7x^2y + a_8xy^2$ (specify 9 values).

7.27 **bounda_force** *index node_range dof_0 dof_1 ...*

States which ones from the list of dof's in which nodes get prescribed nodal forces. The item *node_range* represents a range of node numbers. In stead of a node range also, for example, **-geometry_line 1** can be used, indicating that the nodes on line 1 get the prescribed nodal forces. The items *dof_0* etc. can be one of the items listed at **dof_label**. However, neither **-dis** and **-scal** can be used.

For a specific *index*, only one of **bounda_force** and **bounda_dof** can be specified; thus, either Neumann conditions or Dirichlet conditions can be applied to a particular node, but not both.

Attention: with this option you get the same nodal force on all the specified nodes. If you want to apply a distributed force on a edge, however, you should use **force_edge**. That option gives forces consistent with the displacement field, so not necessarily the same for all nodes. For example the nodes on the side of linear elements on a edge get only half the force.

As a special option you can specify also, by example, **element_geometry 1** in stead of a node range. Then nodes of elements which have **element_group** set to 1 will get the prescribed nodal forces.

Notice: if several **bounda_force** records act on a node, the imposed forces are summed.

See also: **bounda_time**, **bounda_sine** and **force_edge**.

7.28 **bounda_geometry_method** *index node_type*

If boundary conditions are imposed on a geometry, you can set with this record which node type should be used. If *node_type* is set to **-node_start_refined** the values of **-node_start_refined** are used to determine if nodes are located on the geometry. If *node_type* is set to **-node** the values of **-node** are used to determine if nodes are located on the geometry. If *node_type* is set to **-plus_displacement** the values of **-node** plus nodal displacements are used to determine if nodes are located on the geometry.

7.29 **bounda_normal** *index normal_x normal_y normal_z*

This record specifies the components of a normal vector to a plane on which nodes should slide (the nodes are not allowed to move normal to the plane). In 3D you need to specify all of *normal_x normal_y normal_z*. In 2D you need to specify only *normal_x normal_y*. In 1D you need to specify only *normal_x*.

See also **bounda_dof**.

7.30 **bounda_print_mesh_dof** *dof_0 dof_1 ...*

See **print_mesh_dof**.

7.31 **bounda_print_mesh_dof_geometry** *geometry_item_name geometry_item_index*

See **print_mesh_dof**.

7.32 **bounda_print_mesh_dof_values** *value_dof_0 value_dof_1 ...*

See **print_mesh_dof**.

7.33 **bounda_save** *index switch*

See **control_bounda_save**.

7.34 **bounda_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

The **bounda_dof** or **bounda_force** record with the same *index* is imposed with the sum of the sine functions; the first sine function has frequency *freq_0* and amplitude *amp_0*, the second sine function has frequency *freq_1* and amplitude *amp_1*, etc.. More general behavior in time can be imposed by using **bounda_time** records. For a specific *index* only one of **bounda_time** and **bounda_sine** can be specified.

As a typical application the response due to the excitation with a frequency spectrum can be analyzed. Just print the relevant response by **control_print_history** and extract the frequency spectrum of that response signal.

The sine loads will be only imposed after *start_time*, and will not be imposed anymore after *end_time*. The sine functions start at time *start_time* (then they have value 0).

As a special option setting a frequency to 0 enforces tochnog to use a constant static value of the specified amplitude.

7.35 **bounda_time** *index time load time load ...*

This record specifies a multi linear time-load diagram for the **bounda_dof** or **bounda_force** record with the same *index*. Between two time points in the diagram, the load is interpolated linearly (ramp function between the two points).

At all times that an dof is not prescribed in such way, it is free and determined with the governing differential equations. For a specific *index* only one of **bounda_time**, **bounda_sine** and **bounda_time_user** can be specified.

As a special option, you can specify only one value in the **bounda_time** record if the load is constant over time (so not time-load sets but directly the constant load value).

As a further special option, you can specify no **bounda_time** and no **bounda_sine** at all; then a 0 value is assumed.

7.36 **bounda_time_factor** *index factor*

With this record you can specify an multiplication factor to be used for loads specified by **bounda_time**. This option comes handy when you import a time-load table from some external data source, which

uses some other definition of the load as you do in the tochnog input file. By example, if you specify accelerations in metric units but the external source specifies the accelerations as part of the gravity acceleration, you can convert the load in the time-load table with this factor.

Default, if **bounda_time_factor** is not specified, the factor is set to 1.

7.37 **bounda_time_offset** *index time_offset*

With this record you can specify an offset to be used for times specified by **bounda_time**. The actual times will become time offset added to the specified times in **bounda_time**. This option comes handy when you import a time-load table from some external data source, but would like to apply the table at a different moment in time in the calculation. You need to specify *time_offset* in the units that you actually use in your calculation.

7.38 **bounda_time_increment** *index time_increment*

With this record you can specify that the data as specified in **bounda_time** is only the load data, so not time points anymore. The time points are automatically calculated from a fixed time increments (and optionally an initial offset as specified in **bounda_time_offset**. By example:

```
...
bounda_dof 10 -geometry_line -accx
bounda_time 10 0.2 0.78 1.33 ... (acceleration data only)
bounda_time_offset 10 1. (the accelerations start at time 1)
bounda_time_increment 10 0.05 (the increments in time are 0.05)
...
```

In this example the acceleration is 0.2 at time 1, it is 0.78 at time 1.05, etc.

7.39 **bounda_time_units** *factor_time factor_length*

The specified times and data in **bounda_time** may have other units then you actually apply in your calculation. With *factor_time* you correct the time in **bounda_time** to get times consistent with your calculation. With *factor_length* you can correct the data in **bounda_time** to get data consistent with your calculation. By example, if |bf bounda_time contains [sec] and [cm] and if your actual calculation uses [hour] and [m] then set *factor_time* to 3600. and set *factor_length* to 100. This option is presently only available for prescribed accelerations.

7.40 **bounda_time_smc** *index switch*

If *switch* is set to **-yes** the SMC file *index.smc* will be read. Such Strong Motion CD file (SMC file) contains base acceleration time data. This option can be used to read SMC files strictly following the definition from <http://nsmp.wr.usgs.gov/smcfmt.html>. A typical input example for a SMC file looks like:

```
...
```



```

materi_velocity
materi_stress
...
end_initia
...
bounda_baseline_correction 1. 1.1 (correct acceleration for time 1 to 1.1)
...
bounda_dof 10 -geometry_line -accx
bounda_time_smc 10 -yes
bounda_time_smc_offset 10 1. (the base excitation starts at time 1)
bounda_time_smc_units 10 3600. 100. (we use hours and meters)
...
control_timestep 10 1.e-2 1. (gravity from time 0 to 1)
...
control_timestep 20 1.e-6 0.1 (base excitation from time 1 to 1.1)
...

```

In case the SMC file does not strictly follow the definition from <http://nsmp.wr.usgs.gov/smcfmt.html>, the option **bounda_time_smc** cannot be used. In such case you can use the actual data lines in a **bounda_time** record as follows:

```

...
materi_velocity
materi_stress
...
end_initia
...
bounda_baseline_correction 1. 1.1 (correct acceleration for time 1 to 1.1)
...
bounda_dof 10 -geometry_line -accx
include acceleration.dat (include file containing bounda_time 10 ..., the dots ...
represent acceleration data)
bounda_time_offset 10 1. (the base excitation starts at time 1)
bounda_time_units 10 3600. 100. (we use hours and meters)
...
control_timestep 10 1.e-2 1. (gravity from time 0 to 1)
...
control_timestep 20 1.e-6 0.1 (base excitation from time 1 to 1.1)
...

```

Be sure that you take sufficient small time increments while performing the base acceleration steps. See also <http://nsmp.wr.usgs.gov/>.

7.41 **bounda_time_smc_offset** *index time_offset*

The times of the SMC file are incremented with *time_offset*, such that you can use the acceleration data starting from any time point in a calculation. If this record is not specified then *time_offset* is set to 0.

7.42 **bounda_time_smc_units** *factor_time factor_length*

The SMC files have units [cm] for length and [sec] for time. Your input file may have other units however. With *factor_time* you correct the time read from the SMC file to get times consistent with your input file. With *factor_length* you can correct the data (acceleration, velocity or displacement) read from the SMC file to get data consistent with your input file. By example, if you use [hour] and [m] in your calculation then set *factor_time* to 3600. and set *factor_length* to 100.

7.43 **bounda_time_user** *index switch*

If *switch* is set to **-yes** a user supplied routine for the time-load diagram will be used.

See also the file **user.cpp** in the distribution.

7.44 **bounda_water** *index switch*

If *switch* is set to **-yes**, and you specify the pore pressure **-total_pressure** as dof, the pore pressure is actually determined from the height of the water column between the node and the phreatic level. In fact the pore pressure is set to $\text{density_water} \cdot g \cdot \Delta z$ where g is the gravitational acceleration, and Δz is the distance to the phreatic level.

The water density is given by **groundflow_density**. The gravity acceleration is given by the vertical component of **force_gravity**. The water height is relative to the water height is given by **groundflow_phreatic_level**.

In this case the record **bounda_time** does not contain the actual value of the pore pressure, but instead it only contains a multiplication factor for the static water pressure as calculated above.

This **bounda_water** is convenient when the phreatic level is located above the FE mesh. Then this option allows you to impose a pressure boundary condition for the nodes in the FE mesh at the top boundary of the mesh, automatically using a specified phreatic level record.

7.45 **change_dataitem** *index data_item_name data_item_index data_item_number_0 data_item_number_1 ... operat*

With this record you can specify a data item which should be changed over time. The time table should be given in the **change_dataitem_time** table as time-value sets; at least two sets should be specified.

The *operat* determines how the time-value sets are used. If *operat* is set to **-use**, then the value of the time-value sets is directly used. If *operat* is set to **-add**, then the value of the time-value sets is interpreted as a rate of change, so that the value is multiplied with the time step and then added to the old value.

Notice that you can change multiple numbers at once.

As a typical example you can use this to prescribe the displacement of a contact geometry over time. Below the y-coordinates of a geometry line which is used in the contact algorithm is changed over time:

contact_target_geometry 0 -geometry_line 1

```

...

geometry_line 1 0. 10. 2. 10.
...

change_dataitem 0 -geometry_line 1 1 -use
change_dataitem_time 0 0. 10. 100. 0.
change_dataitem 1 -geometry_line 1 3 -use
change_dataitem_time 1 0. 10. 100. 0.
...

```

7.46 **change_dataitem_geometry** *index geometry_entity_name geometry_entity_index*

For element group data **group_*** you can restrict the application for the **change_dataitem** to only those elements which are part of the geometry specified by *geometry_entity_name geometry_entity_index*.

7.47 **change_dataitem_time** *index time value ...*

See **change_dataitem** and **change_dataitem_time_user**.

7.48 **change_dataitem_time_discrete** *index switch*

If *switch* is set to **-yes** then the changes applied by the **change_dataitem** and **change_dataitem_time** records (with the same index), will be applied at the discrete time points given in **change_dataitem_time**. Between those time points, no interpolation is used.

More precise, the change of the data item will be applied directly after the time point has passed.

If you don't specify this **change_dataitem_time_discrete** record then interpolation is used.

7.49 **change_dataitem_time_method** *index method*

With this record you can require that the cosinus, sinus or tangent of a data value will be changed (in stead of the data value directly itself). The *method* can be set to either **-cosinus**, **-sinus** or **-tangent**. This is typically convenient for geotechnical safety factor calculations where you want that for a mohr coulomb law the cohesion and tangent of the friction angle are decreased at the same ratio in time.

Example:

```

...
group_materi_plasti_mohr_coul_direct 10 ...
...
(tangent of friction angle reduction)
change_dataitem_time 10 -group_materi_plasti_mohr_coul_direct 10 0 -use
change_dataitem_time_method 10 -tangent
change_dataitem_time 10 ... (specify tangent values here)

```

```

...
(cohesion reduction)
change_dataitem_time 20 -group_materi_plasti_mohr_coul_direct 10 1 -use
change_dataitem_time 20 ...
...

```

7.50 `change_dataitem_time_user` *index switch*

If *switch* is set to **-yes** a user supplied subroutine is used instead of the `change_dataitem_time` table.

See also the `user.cpp` routine included in the distribution.

7.51 `check_data` *switch*

If *switch* is set to **-yes** the in-core database is checked at some moments during the calculation. You can try this option in case you experience unexpected behavior.

7.52 `check_error` *switch*

Tochnog will does some error checking which you can suppress by setting *switch* to **-no**.

7.53 `check_element_node` *index switch*

Tochnog will check that elements do not have duplicate nodes. If you want to have duplicate nodes on purpose however, you can set *switch* to **-no** so that this checking is suppressed.

7.54 `check_element_shape` *index factor*

Isoparametric elements are mapped from the isoparametric space to the real coordinate space with shape functions. The determinant of the Jacobian of the mapping will have the same value in each integration point if elements are not distorted by the mapping. Thus the relative difference $\frac{det_{ip} - det_{average}}{det_{average}}$ in each integration point of an element measures the distortion.

Tochnog determines the average of the relative difference for all the integration points in an element.

If this average is larger then *factor* a warning message will be printed. Furthermore, if `check_element_shape` is specified the average will be stored in a record `element_shape` in the database `db`s file; the average will be plotted in the GID post-processing files so that you can visually inspect where the elements are most distorted.

Perfectly non-distorted isoparametric elements have average 0.

Severely distorted elements have a high average, e.g. larger than 0.25.

7.55 **check_memory** *index switch*

If *switch* is set to **-yes**, Tochnog checks memory usage of the calculation. If *switch* is set to **-no**, Tochnog does not check memory usage of the calculation.

When checking memory usage Tochnog checks that the calculation fits in the computer RAM memory. Furthermore, on 32 bit systems Tochnog checks that array sizes do not exceed 2Gb.

Default, if **check_memory** is not specified, the *switch* is set to **-no**.

7.56 **check_memory_usage** *index switch*

If *switch* is set to **-yes** Tochnog keeps record of the highest memory used by the calculation. It will put that highest usage, expressed in GB, in the record **check_memory_usage_result**. This option comes convenient to keep an eye on the memory usage of a calculation, in case you are reaching the limit on your computer. You need to prevent that memory usage exceeds the amount of RAM memory, since swapping to disk is extremely slow.

This option is only available on 64 bit linux.

7.57 **check_memory_usage_result** *index memory*

See **check_memory_usage**.

7.58 **check_nan** *switch*

If *switch* is set to **-yes** some internal result (stresses, etc.) are check for being NAN. NAN represents Not A Number , meaning that the computer cannot represent the result by a number. This means that something is wrong: the solution may have diverged, or you may have a programming error in a user supplied routine, or etc.

7.59 **check_solver** *eps*

If this record is set the solver checks if diagonal terms are smaller than *eps*. That normally indicates some problem in your input file if *eps* is very small.

7.60 **check_warning** *switch*

Tochnog will does some warning checking which you can suppress by setting *switch* to **-no**.

7.61 **condif_convection_edge_normal** *index α_c T_r*

Convection coefficient and convection environmental temperature. Also the record **condif_convection_edge_n** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

7.62 `condif_convection_edge_normal_element` *index element_0 element_1 ...*

Selects the elements for which the `condif_convection_edge_normal` record with the same *index* should be applied.

7.63 `condif_convection_edge_normal_element_group` *index element_group_0 element_group_1 ...*

Selects the element groups for which the `condif_convection_edge_normal` record with the same *index* should be applied.

7.64 `condif_convection_edge_normal_element_node` *index element node_0 node_1 ...*

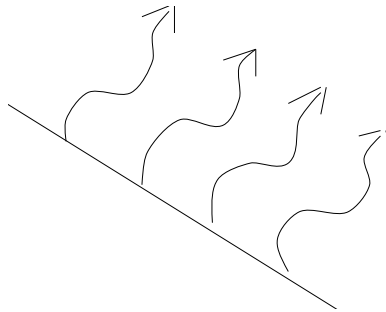
Selects the element and local node numbers for which the `condif_convection_edge_normal` record with the same *index* should be applied.

7.65 `condif_convection_edge_normal_element_side` *index element_0 element_1 ... side*

Selects the elements and local side number for which the `condif_convection_edge_normal` record with the same *index* should be applied.

7.66 `condif_convection_edge_normal_geometry` *index geometry_entity_name geometry_entity_index*

Selects the area for which the `condif_convection_edge_normal` record with the same *index* should be applied.



Instead of a number of nodes also, for example, `-geometry_line 1` can be used in 2D, indicating that the nodes on line 1 start to convect. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges. See also: `condif_convection_edge_normal`.

7.67 `condif_convection_edge_normal_node` *index node_0 node_1 ...*

Selects the nodes for which the `condif_convection_edge_normal` record with the same *index* should be applied. The *node_0* etc. specifies the global node numbers.

7.68 **condif_heat_edge_normal** *index heat*

Distributed prescribed heat flux in the direction of the outward normal at the edge of a element. This distributed heat is translated into equivalent nodal heat on the edges of elements. Also the record **condif_heat_edge_normal_geometry** should be specified, and optionally the record **condif_heat_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this option is used INSIDE a FE mesh, then the elements on each side will get the distributed heat. So the total heat flux will normally become zero since the normals of the elements at the side of the geometry are opposite.

7.69 **condif_heat_edge_normal_element** *index element_0 element_1 ...*

Restricts the elements to which the **condif_heat_edge_normal** record with the same *index* should be applied.

7.70 **condif_heat_edge_normal_element_group** *index element_group_0 element_group_1 ...*

Restricts the element groups to which the **condif_heat_edge_normal** record with the same *index* should be applied.

7.71 **condif_heat_edge_normal_element_node** *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **condif_heat_edge_normal** record with the same *index* should be applied.

7.72 **condif_heat_edge_normal_element_node_factor** *index factor_0 factor_1 ...*

Nodal multiplication factors with which the **condif_heat_edge_normal** will be applied to the element of **condif_heat_edge_normal_element_node**. You need to specify a factor for each node on the side. Here *factor₀* is the multiplication factor for the first node on the side, etc.

7.73 **condif_heat_edge_normal_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **condif_heat_edge_normal** record with the same *index* should be applied.

7.74 **condif_heat_edge_normal_factor** *index a₀ a₁ ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **condif_heat_edge_normal** records (with the same *index*). In this way, you can obtain coordinate dependent heat fluxes.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if $n=2$ the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if $n=5$ the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if $n=8$ the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.75 **condif_heat_edge_normal_geometry** *index geometry_entity_name geometry_entity_index*

Selects the area for which the **condif_heat_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed heat. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.76 **condif_heat_edge_normal_node** *index node_0 node_1 node_2 ...*

Selects the nodes for which the **condif_heat_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.77 **condif_heat_edge_normal_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to **force_edge_sine**, now for heat flux however.

7.78 **condif_heat_edge_normal_time** *index time load time load ...*

This record specifies a diagram which contains the factors with which the **condif_heat_edge_normal** record with the same *index* is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the heat flux is applied at all times with a factor 1.

7.79 **condif_heat_volume** *index heat*

Distributed volume heat source. Here *heat* is the distributed heat source value.

See also **condif_heat_volume_factor**, **condif_heat_volume_geometry**, and **condif_heat_volume_time**.

7.80 **condif_heat_volume_element** *index element_0 element_1 ...*

Specifies the elements for which the **condif_heat_volume** record with the same *index* should be applied.

7.81 **condif_heat_volume_element_group** *index element_group*

Specifies the element group for which the **condif_heat_volume** record with the same *index* should be applied.

7.82 **condif_heat_volume_factor** *index a₀ a₁ ... a_n*

This polynomial gives a factor which is used as a multiplication factor for **condif_heat_volume** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if n=2 the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if n=5 the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if n=8 the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.83 **condif_heat_volume_geometry** *index geometry_name geometry_index*

Specifies the geometry for which the **condif_heat_volume** record with the same *index* should be applied.

7.84 **condif_heat_volume_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to **force_edge_sine**, now for volume heat source however.

7.85 **condif_heat_volume_time** *index time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **condif_heat_volume** record with the same index is applied.

If this record is not specified, the heat source is applied at all times with a factor 1.

7.86 **condif_heat_volume_user** *index switch*

Set *switch* to **-yes** if you want to call the user supplied routine for heat.

7.87 **condif_heat_volume_user_parameters** *index ...*

Specify the parameters for the user supplied routine for heat.

7.88 **condif_radiation_edge_normal** *index* α_r T_r

Radiation coefficient and radiation environmental temperature. Also the record **condif_radiation_edge_norm** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

7.89 **condif_radiation_edge_normal_element** *index element_0 element_1 ...*

Selects the elements for which the **condif_radiation_normal_edge** record with the same *index* should be applied.

7.90 **condif_radiation_edge_normal_element_node** *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **condif_radiation_edge_normal** record with the same *index* should be applied.

7.91 **condif_radiation_edge_normal_element_group** *index element_group_0 element_group_1 ...*

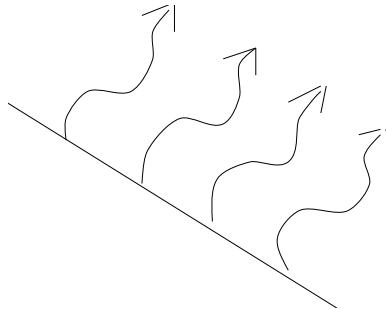
Selects the element groups for which the **condif_radiation_normal_edge** record with the same *index* should be applied.

7.92 **condif_radiation_edge_normal_element_side** *index element_0 element_1 ... side*

Selects the elements and side number for which the **condif_radiation_edge_normal** record with the same *index* should be applied.

7.93 **condif_radiation_edge_normal_geometry** *index geometry_entity_name geometry_entity_index*

Selects the area for which the **condif_radiation_edge_normal** record with the same *index* should be applied.



In stead of a number of nodes also, for example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 radiate heat. The total edge of an element must be inside the geometry

for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges. See also: **condif_radiation_edge_normal**.

7.94 **condif_radiation_edge_normal_node** *index node_0 node_1 ...*

Selects the nodes for which the **condif_radiation_edge_normal** record with the same *index* should be applied. This is only available for linear elements. The *node_0* etc. specifies the global node numbers.

7.95 **contact_apply** *index switch*

If *switch* is set to **-yes**, the contact algorithm is used. If *switch* is set to **-no**, the contact algorithm is not used. This is done for all timestep records.

See also **control_contact_apply**.

7.96 **contact_heat_generation** *factor*

This *factor* specifies how much of the frictional energy is transformed into heat (this only makes sense if *friction* in **contact_plasti_friction** is not zero, and if **condif_temperature** is initialized). The *factor* should be between 0 and 1. See also **contact_target_geometry**.

7.97 **contact_penalty_pressure** *pressure_penalty*

The *pressure_penalty* should be given some high value if the pressure is freely linked at the surfaces of contactor and target. See also **contact_target_geometry**.

7.98 **contact_penalty_temperature** *temperature_penalty*

The *temperature_penalty* should be given some high value if free heat exchange between contactor and target is possible. See also **contact_target_geometry**.

7.99 **contact_penalty_velocity** *velocity_penalty*

The **velocity_penalty** essentially puts a spring between the contactor and the target if penetration occurs. Iterations (see **control_timestep_iterations**) are needed; more iterations are needed if the penalty factor is higher. See also **contact_target_geometry**.

7.100 **contact_plasti_friction** *friction*

See **contact_target_geometry**.

7.101 **contact_target_element_group** *element_group_0 element_group_1 ...*

This records defines the element groups for which the elements function as target in a contact analysis. It is advised to use different element groups for the contacting and target elements, so that the contact algorithm can distinguish between both. The target element group should consist of more than 1 layer of elements in contact direction (so only one layer of target elements is not allowed). The contactor should be smaller of size than the target.

See also **contact_target_geometry**.

7.102 **contact_target_geometry** *index geometry_entity_item geometry_entity_index*

This record specifies a contact geometry. Contacting nodes are forced to stay at the outward normal side of the contact geometry.

The allowed geometries and their material outward normals are listed below

- If a **geometry_point** is used in 1D, the normal is in positive x-direction.
- If a **geometry_line** is used in 2D, the normal is the outer product of 3-direction and the line direction (from point 0 to point 1).
- If a **geometry_circle** is used in 2D, the normal is the outward direction at the circle.
- If a **geometry_circle** is used in 3D, the normal is the outward direction on the circle surface.
- If a **geometry_ellipse** is used in 2D, the normal is the outward direction at the ellipse.
- If a **geometry_sphere** is used in 3D, the normal is the outward direction at the sphere.
- If a **geometry_polynomial** is used in 2D, the normal is in positive y-direction.
- If a **geometry_polynomial** is used in 3D, the normal is in positive z-direction.
- If a **geometry_triangle** is used in 3D, the normal is in direction of the outer product $v01 * v02$ where $v01$ is the vector from node 0 to node 1 and $v02$ is the vector from node 0 to node 2.
- If a **geometry_quadrilateral** is used in 3D, the normal is in direction of the outer product $v01 * v02$ where $v01$ is the vector from node 0 to node 1 and $v02$ is the vector from node 0 to node 2. Only non-distorted quadrilaterals should be used.

This normal can be switched sign by setting the **contact_target_geometry_switch** with the same *index* to **-yes**.

In stead of geometries, also contact with target elements will be checked. Only contact with the elements **-bar2**, **-quad4**, and **-hex8** can be detected. Specify **contact_target_element_group** for this.

The time steps should be such small, that contacting nodes penetrate the other elements only in small steps.

If a **contact_target_geometry** is used, then the contacting node should also be within the tolerance of the geometrical entity to be noticed!

If contact is detected, normal contact forces of size *contact_penalty_velocity* * penetration are generated between the contacting node and the other element. Moreover, also a frictional force of size *friction* * normal force is generated (see **contact_plasti_friction**).

With contact you need more iterations the normal, say 5 or more. See **control_timestep_iterations** how to define the number of iterations.

7.103 **contact_target_geometry_switch** *index switch*

See **contact_target_geometry**.

7.104 **control_bounda_relax** *index switch*

With this **control_bounda_relax** you can require Tochnog to store the nodal right-hand-sides; by example external nodal forces for nodes with prescribed velocities. These stored nodal right-hand-sides can later be used to relax prescribed boundary conditions; by example a prescribed velocity is removed and substituted by the stored external right-hand-side (external force) and slowly set to zero by multiplication with a time function as specified with **bounda_force** in combination with **bounda_time**. With the **control_bounda_relax_geometry** record with the same index you can select a specific geometry for which the storing will be done.

A typical example can be found in the **relax1.dat** file in your distribution.

7.105 **control_bounda_relax_geometry** *index geometry-item_name geometry-item_index*

See **control_bounda_relax**.

7.106 **control_bounda_save** *index switch*

If *switch* is set to **yes** the boundary conditions are considered to remain the same after the first timestep in a **control_timestep*** block, and the **bounda_dof** and **bounda_force** records are not analysed in further timesteps. This saves calculation time for analysing the boundary conditions in each and every timestep in the timestep block.

Alternatively you can also specify **bounda_save** which specifies this option for all timestep blocks in the calculation.

7.107 **control_check_data** *index switch*

If *switch* is set to **-yes** the in-core database is checked at some moments during the calculation, for the specified control index. You can try this option in case you experience unexpected behavior.

7.108 **control_contact_apply** *index switch*

If *switch* is set to **-yes**, the contact algorithm is used. If *switch* is set to **-no**, the contact algorithm is not used. This is done for timestep records with the same index.

Default *switch* is set to **-yes**. See also **contact_apply**.

7.109 **control_convection_apply** *index switch*

If *switch* is set to **-yes**, the convection of a material with respect to the mesh is allowed. If *switch* is set to **-no**, the convection of a material with respect to the mesh is not allowed. This is done for timestep records with the same index. See also **convection_apply**.

7.110 **control_crack** *index ...*

See **crack_element_group**.

7.111 **control_data_activate** *index data_item_name_0 data_item_name_1 ... switch*

With this record you can set data items to become activated if *switch* is set to **-yes** or de-activated if *switch* is set to **-no**. The *data_item_name* specifies a data record name.

This option is still experimental; results should be checked.

7.112 **control_data_arithmetic** *index data_item_name data_item_index data_item_number operat*

This record allows you to change a data item. With *data_item_name data_item_index data_item_number* you select which data item to change. It will be changed with value *val* as specified in the corresponding **control_data_arithmetic_double** record. With *operat* you select how to change the data item; possibilities are **-plus**, **-minus**, **-multiply** and **-divide**.

In stead of a specific index *data_item_index* you can also specify a range **-ra ... -ra**.

In case you specify **-all** for *data_item_number* the specified value will be used for all numbers of the record.

7.113 **control_data_arithmetic_double** *index val*

See **control_data_arithmetic**.

7.114 **control_data_copy** *index data_item_from data_item_to*

Copy data item *data_item_from* to *data_item_to*. The user is responsible to apply only logic copy actions.

Normally the *data_item_from* and *data_item_to* should have the same length. As a special option however, you can copy **node_inertia** to **node_force** records, while using a **control_data_copy_factor** of -1. This allows you to substitute material mass inertia by static nodal forces, for the remainder of the calculation. This in fact is the d’alembert principle.

7.115 **control_data_copy_factor** *index factor*

Multiplication factor for **control_data_copy**.

7.116 **control_data_copy_index** *index data_item_from index_from data_item_to index_to*

Copy data item *data_item_from* with index *index_from* to *data_item_to* with *index_to*. The user is responsible to apply only logic copy actions.

7.117 **control_data_copy_index_factor** *index factor*

Multiplication factor for **control_data_copy_index**.

7.118 **control_data_delete** *index data_item_name index_range*

Delete one or more data items. The *index_range* is a number (e.g. 3) or a range (**-ra ... -ra**, or **-all**).

If *index data_item_name* is a nodal item (for example **node** or **node_dof**) then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be deleted for nodes located on the geometrical entity.

If *index data_item_name* is a element item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be deleted for elements with all nodes located on the geometrical entity.

In the example below element 1-10 and nodes 1-100 are deleted after some time in the calculation; this simulates dismantling a part of a structure somewhere in its lifetime. First, time steps with the total structure are taken; then a part of the structure is dismantled; then time steps with the remaining part of the structure are taken.

```
...
control_timestep 10 ...
...
control_data_delete 20 -element -ra -from 1 -to 10 -ra
control_data_delete 21 -node -ra -from 1 -to 100 -ra
...
control_timestep 30 ...
...
```

If an element or node is deleted, then also the corresponding records will be deleted. See also **control_data_put**.

7.119 **control_data_put** *index data_item_name index_range number_0 number_1 ...*

Puts one or more data items.

The *index_range* is a number (e.g. 3) or a range (**-ra ... -ra**, or **-all**). The **-all** option for *index_range* is only available for nodal data items (like **node** or **node_dof**). If *data_item_name* is a nodal item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be put for nodes located on the geometrical entity. If *data_item_name* is a

element item then *index_range* can also be a geometrical entity (for example **-geometry_line 1** or so), and the item will be put for elements with all nodes located on the geometrical entity.

With *number_0 number_1* etc. you can set which value should be put. For example only using 3 for *number_0* then you only want to set the fourth value for the data item (remember that numbering starts at 0). To specify the numbers for dof's you can also specify names like **-velx**, **-sigxx**, etc. In case you specify **-all**, then all values should be given in **control_data_put_double** or **control_data_put_integer**.

The values to be put should be specified in a **control_data_put_double** record for real data or in a **control_data_put_integer** record otherwise. You should specify a value for each and every specified number.

If the data item already exists it is overwritten; else a new record will be generated.

See also **control_data_delete**.

7.120 **control_data_put_double** *index ...*

See **control_data_put**.

7.121 **control_data_put_integer** *index ...*

See **control_data_put**.

7.122 **control_data_save** *index switch*

If *switch* is set to **-yes** save the status of strains, stresses, displacements, etc. At a later point in the calculation you can plot with gid data relative to these saved data with **control_print_gid_save_difference**.

```
...
control_timestep 10 ...
...
control_data_save 20 -yes
...
control_timestep 30 ...
...
control_print_gid 40 -separate_sequential
control_print_gid_save_difference 40 -yes
...
```

7.123 **control_dependency_apply** *index switch*

If *switch* is set to **-yes**, dependencies as specified with **dependency_diagram** and **dependency_item** are included in the calculation. If *switch* is set to **-no**, these dependencies are not included. This is done for timestep records with the same index.

Default, if **control_dependency_apply** is not specified, then **dependency_apply** will be used.

7.124 **control_distribute** *index distribution_type data_item_name data_item_index data_item_number*

Apply a random number, based on a **-lognormal** or **-normal** distribution, to the *data_item_name* records. This is done for the index *data_item_index* and the *data_item_number* value in those records (0 for the first value, 1 for the second value, etc.). The *data_item_index* can optionally be set to **-all** in stead of a specific index, so that the distribution will be applied to all existing indices.

The *distribution_type* should be set to **-lognormal** or **-normal**. Use the **control_distribute_parameters** record to set the mean value and standard deviation.

If you specify a group item for *data_item_name*, for example **group_materi_elasti_young** or so, then not the group item record self will be changed, but the item will be changed for the elements which use this record; in this way you can give a random distribution to element data like stiffness, plastic properties, etc.

For group data **group_***, element data **element_*** and nodal data **node_*** it is optionally possible to require a distribution that is correlated in space. To obtain such a correlated distribution, you need to specify the **control_distribute_correlation_length** record. If the specified correlation length is larger than 1.e12 then Tochnog uses a constant G (all components have the same value). As a special option, you can specify a different distribution length in each space direction (in 2D specify 2 values, and in 3D specify 3 values).

With **control_distribute_correlation_distance** you can set the maximum distance below which element or nodal data will be correlated. Above that distance tochnog will not correlate the data. Default, if **control_distribute_correlation_distance** is not specified it will be taken to be 4 times the correlation length.

With **control_distribute_minimum_maximum** you can set the minimum and maximum value which the random numbers are allowed to take. Numbers outside that range will be cutoff to the minimum or maximum value. A typical application would be limiting the void ratio to a range which is needed by a hypoplasticity law.

In the first example, an lognormal distribution with average 100 and standard deviation 1.2 is used to the nodal temperatures:

```
...
materi_velocity
condif_temperature
...
control_distribute 10 -lognormal -node_dof -all -temp
control_distribute_parameters 10 100. 1.2
...
```

In the second example, a normal distribution with average 1 and standard deviation 1.e-3 is used to the y coordinate of the nodes:

```
...
control_distribute 10 -normal -node -all 1
control_distribute_parameters 10 1. 1.e-3
...
```

In the third example, a normal distribution with average 10 and standard deviation 1. is used to the young's modulus of group 7:

```
...
control_distribute 10 -normal -group_materi_elasti_young 7 0
control_distribute_parameters 10 10. 1.
...
```

This **control_distribute_*** is presently only available on linux computers.

7.125 control_distribute_correlation_distance *index maximum_distance*

7.126 control_distribute_correlation_length *index correlation_length ...*

See **control_distribute**.

7.127 control_distribute_minimum_maximum *index minimum maximum*

See **control_distribute**.

7.128 control_distribute_parameters *index mean_value standard_deviation*

See **control_distribute**.

7.129 control_distribute_seed *index seed*

For experts only. With this record you can specify the seed which will be used to start the random series of numbers. Use a positive integer value.

As a special option you can set *seed* to **-new** then Tochnog will self choose a seed. As a special option you can set *seed* to **-old** then Tochnog will use the previous seed.

7.130 control_groundflow_consolidation_apply *index switch*

If *switch* is set to **-no**, then the material divergence part in the groundflow equation is skipped.

Attention: If you want consolidation in geotechnics then set the *switch* to **-yes**. If you do not want consolidation in geotechnics then set the *switch* to **-no**.

This is done for timestep records with the same index.

Default, if **control_groundflow_consolidation_apply** is not specified, then **groundflow_consolidation_apply** will be used.

7.131 **control_groundflow_nonsaturated_apply** *index switch*

If *switch* is set to **-no**, then nonsaturated groundflow data (eg van Genuchten) will not be applied; only saturated data will be used.

Default, if **control_groundflow_nonsaturated_apply** is not specified, then **groundflow_nonsaturated_apply** will be used.

7.132 **control_inertia_apply** *index switch_0 switch_1 ...*

If *switch_0* is set to **-yes**, the corresponding inertia term is included (material mass, heat capacity, ..). The same for the other switches. A switch should be specified for each of the principal dof's. See the 'input file - data part - introduction - types of dof's' section for an explanation about principal dof's. The sequence of the principal dof's is in the order as initialised in the **initia ... end_initia** part.

As a special option you can specify only one switch, and then the specified value will automatically be used for all principal dof's.

This **control_inertia_apply** record is applied for timestep records with the same index.

Default, if **control_inertia_apply** is not specified, then **inertia_apply** will be used.

7.133 **control_input** *index switch*

If *switch* is set to **-yes** Tochnog reads an extra piece of input from the file *index.dat*. The piece of input needs to be closed by two **end_data** statements. Comments (...) are not allowed. All defines and arithmetics cannot be used.

7.134 **control_interface_gap_apply** *index switch*

If *switch* is set to **-yes** then any **group_interface_gap** will be applied. If *switch* is set to **-no** then any **group_interface_gap** will be ignored.

Default, if **control_interface_gap_apply** is not specified, *switch* is set to **-yes**.

7.135 **control_materi_damage_apply** *index switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with damage data. See also **materi_damage_apply**.

7.136 **control_materi_elasti_k0** *index switch*

See **group_materi_elasti_k0**.

7.137 **control_materi_failure_apply** *index switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with failure data. See also **materi_failure_apply**.

7.138 **control_materi_plasti_hypo_masin_ocr_apply** *index switch*

If *switch* is set to **-yes** the OCR will be applied. If *switch* is set to **-no** the OCR will not be applied.

Default *switch* is **-no**.

7.139 **control_materi_plasti_hardsoil_gammap_initial** *index switch*

See theory section on hardsoil.

7.140 **control_materi_plasti_hypo_pressure_dependent_void_ratio** *index switch*

If *switch* is set to **-yes** the initial void ratio is corrected for pressure dependency; see the theory section. This is done for the first timestep in the corresponding **control_timestep** record with the same *index*. Default *switch* is set to **-no**.

7.141 **control_materi_plasti_hypo_niemunis_visco_ocr_apply** *index switch*

If *switch* is set to **-yes** the OCR will be applied. If *switch* is set to **-no** the OCR will not be applied.

Default *switch* is **-no**.

7.142 **control_materi_plasti_hypo_substepping** *index switch*

If *switch* is set to **-yes** substepping will be applied in hypoplasticity routines. If *switch* is set to **-no** substepping will not be applied in hypoplasticity routines.

If this record is not specified the record **materi_plasti_hypo_substepping** will be used.

7.143 **control_materi_plasti_visco_apply** *index switch*

If *switch* is set to **-no**, any visco-plasticity data in the input file will be ignored. This is done for timestep records with the same index.

See also **materi_plasti_visco_apply**.

7.144 **control_materi_undrained_apply** *index switch*

See **group_materi_undrained_capacity**. Default, if **control_materi_undrained_apply** is not specified, *switch* is set to **-yes**.

7.145 **control_materi_visocity_apply** *index switch*

If *switch* is set to **-no**, any viscosity in the input file will be ignored. This is done for timestep records with the same index.

7.146 **control_mesh_activate_gravity_apply** *index index_0 index_1 ...*

With this record you can specify which of the **mesh_activate_gravity_*** records should be applied, by specifying the indices of the records that should be applied. In case this **control_mesh_activate_gravity_apply** is not given, all **mesh_activate_gravity_*** records will be applied. As a special option you can use **-all** indicating that all of the **mesh_activate_gravity_*** records should be applied (this is the same as not specifying the **control_mesh_activate_gravity_apply** record at all). As another special option you can use **-none** indicating that none of the **mesh_activate_gravity_*** records should be applied.

See also **mesh_activate_gravity_time**.

7.147 **control_mesh_adjust_geometry** *index geometry_entity_item_0 geometry_entity_index_0 geometry_entity_item_1 geometry_entity_index_1*

The nodes of the geometry entity 0 are replaced such that they neatly follow the boundary of geometry 1. In this way, it is easy to make a mesh with elements precisely in specific regions, if this is required to give separate **element_group** data (e.g. materials) to the geometry and it is too difficult to make the mesh at once OK for this.

The created mesh may be quite distorted.

7.148 **control_mesh_change_element_group** *index element_group_0 element_group_1*

Change the group number **element_group** of elements from *element_group_0* to *element_group_1*.

7.149 **control_mesh_convert** *index switch*

If *switch* is set to **-yes**, tochnog will automatically convert elements:

- **-bar2** in 2D to **-quad4** if the element is an interface or hinge
- **-bar3** in 2D to **-quad6** if the element is an interface or hinge
- **-tria3** in 3D to **-prism6** if the element is an interface or hinge
- **-tria6** in 3D to **-prism12** if the element is an interface or hinge
- **-quad4** in 3D to **-hex8** if the element is an interface or hinge

- **-quad8** in 2D to **-quad6** if the element is an interface or hinge
- **-quad8** in 3D to **-hex18** if the element is an interface or hinge
- **-quad9** in 2D to **-quad6** if the element is an interface or hinge
- **-quad9** in 3D to **-hex18** if the element is an interface or hinge
- **-hex20** in 3D to **-hex18** if the element is an interface or hinge
- **-hex20** in 3D to **-hex27** if the element is not an interface or hinge
- **-prism15** in 3D to **-prism12** if the element is an interface or hinge
- **-prism15** in 3D to **-prism18** if the element is not an interface or hinge

For an interface you need to specify interface data in the **group_interface....** For a hinge you need to specify hinge data in the **group_hinge....** By example the **-bar2** is connected to two nodes, whereas the converted **-quad4** is connected to four nodes. In a similar manner all other converted elements also get extra nodes. This options makes it easy to obtain a mesh with interface elements or hinge elements. By example generate with GID in a 2d mesh bar elements, insert group data, and use **control_mesh_convert** to generate the interface elements. This generation of interfaces only works properly if certain conditions are satisfied:

- Each interface needs to have only isoparametric neighbours which have a total side in common with the interface. By example a **-hex8** interface should only have **-hex8** neighbours.
- Surfaces with interface elements should not intersect with another surface with interface elements.

The new generated nodes will be connected to existing neighbouring element at the interfaces. The **control_mesh_convert** tries to do that automatically correct. You can help however by specifying in the record **control_mesh_convert_element_group** element groups which are located at one side of the interfaces (by example the groups of a pile in soil when an interface is generated between pile and soil).

Example in which a **-bar2** interface becomes a **-hex8** interface:

```
...
number_of_space_dimension 3
...
end_initia
...
element 1 -bar2 101 102
element_group 1 10
...
group_interface 10 -yes
...
control_mesh_extrude 100 ...
...
control_mesh_convert 110 -yes
...
```

If *switch* is set to **-no**, tochnog will not convert elements.

7.150 `control_mesh_convert_element_group` *index element_group_0 element_group_1*
...

See `control_mesh_convert`.

7.151 `control_mesh_convert_quad9_quad6` *index dir*

Convert **quad9** into **quad6** is a 2D calculation. With *dir* you can decide in which isoparametric direction of the **quad9** nodes should be deleted (so that becomes the linear direction in the **quad6** element). Set *dir* either to **-x** or to **-y**.

7.152 `control_mesh_convert_tria6_tria3` *index switch*

Convert **tria6** into **tria3** is a 2D calculation. This is done if *switch* is set to **-yes**.

7.153 `control_mesh_delete_element` *index number_0 number_1* ...

The elements with numbers *number_0 number_1* will be deleted. Otherwise the same as `control_mesh_delete_geometry`.

7.154 `control_mesh_delete_geometry` *index geometry_entity_item geometry_entity_index*

All elements which are part of the geometry item are deleted. In this way, it is easy to make a mesh with holes, tunneling systems in ground, etc. Remaining nodes in the geometry, are moved onto the edge of the geometry if the corresponding `control_mesh_delete_geometry_move_node` record with the same index is set to **-yes**; (otherwise, the remaining nodes are left inside the geometry).

For a **geometry_point**, elements inside the tolerance distance of the point will be deleted. For a **geometry_circle**, elements in the total inner area of the circle radius plus its tolerance will be deleted. Likewise for other geometries.

If you combine this record with a **control_timestep** record, then the element will be slowly deleted, starting from a complete element at the start of the timestep up to no element at the end of the timestep. This is accomplished by reducing the nodal forces of the elements slowly to zero; at the end of the timestep, the element is deleted completely. This might be useful for a better convergence behavior of the iterative process.

If an element is being deleted, **element_empty** is automatically set to **-empty**, even if the element is not completely deleted yet. This allows you to look with GID 'behind elements that are being deleted' (see also **element_empty** and **control_print_gid_empty**).

See also `control_mesh_delete_geometry_move_node`, `control_mesh_delete_geometry_element` and `control_mesh_delete_geometry_element_group`.

7.155 `control_mesh_delete_geometry_element` *index element_name_0 element_name_0*
...

Only elements with names *element_name_0* etc. will be deleted if the `control_mesh_delete_geometry` (with the same index) is used. For example, *element_name_0* is **-quad4**, **-beam**, etc.

If this record is not specified all elements in the geometry will be deleted.

7.156 control_mesh_delete_geometry_element_group *index element_group_0 element_group_1 ...*

Only elements from group *element_group_0* etc. will be deleted if the **control_mesh_delete_geometry** (with the same index) is used.

7.157 control_mesh_delete_geometry_factor *index factor_0 factor_1 ...*

The elements deleted by **control_mesh_delete_geometry** (with the same index), will be deleted by a factor *factor_0* at the start of the timesteps up to a factor *factor_1* at the end of the timesteps. If the **control_mesh_delete_geometry** is not used in combination with timesteps, then directly *factor_1* will be applied.

If *factor_1* exceeds $1. - 1.e - 10$ an element will be completely deleted from the calculation, that is the **element** record will be removed and cannot be reactivated in any way later in the calculation.

If this record is not specified then *factor_0* = 0 and *factor_1* = 1.

7.158 control_mesh_delete_geometry_method *index method*

Determines the condition on which an element will be considered part of the geometry to be deleted. If *method* is set to **-all** then all element nodes should be part of the geometry. If *method* is set to **-any** then any of the element nodes should be part of the geometry. If *method* is set to **-average** then the average element coordinate should be part of the geometry.

Default this record is **-all**.

See also **control_mesh_delete_geometry**.

7.159 control_mesh_delete_geometry_move_node *index switch*

Determines if remaining nodes inside a deleted geometry, are moved onto the edge of the geometry (**-yes**) or not (**-no**). Moving nodes makes that the element mesh exactly fits the deleted geometry, but may also lead to heavily distorted elements. Default this record is **-no**.

See also **control_mesh_delete_geometry**.

7.160 control_mesh_delete_geometry_projection_type *index type*

This record allows you to control what geometry will actually be deleted. Set *type* to **-project_inside** or **-project_exact**. For example if the geometry is a **geometry_circle** then **-project_inside** means that everything inside the circle will be deleted, whereas **-project_exact** means that everything within a tolerance from the circle edge will be deleted. Default *type* is **-project_inside**.

7.161 **control_mesh_delete_geometry_stop** *index switch*

If *switch* is set to **-yes**, any deleting of elements in geometries will be stopped. That is, all remaining delete factors from **control_mesh_delete_geometry_factor** will be destroyed and all elements will become fully active again.

In combination with **global_element_dof_apply -yes**, the elements which become active again will take their strains, stresses etc. of the moment just before being deleted! If you want to lower the stresses or strains or so, then consider using **control_reset_dof**.

In combination with **global_element_dof_apply -no**, the elements which become active again will take their strains, stresses etc. from the nodes.

7.162 **control_mesh_delete_geometry_stop_geometry** *index geometry_entity_name geometry_entity_index*

Only do the **control_mesh_delete_geometry_stop** for elements part of the geometrical entity specified in this **control_mesh_delete_geometry_stop_geometry**.

7.163 **control_mesh_delete_small** *index eps*

At the end of a timestep, an element will be deleted when its volume has become smaller than *eps*.

7.164 **control_mesh_duplicate_element_group** *index element_group_old element_group_new*

Use this command to duplicate elements from group *element_group_old* to new elements with group *element_group_new*. The new elements get the same nodes as the old original elements.

7.165 **control_mesh_extrude** *index z0 z1 z2 ...*

Option to extrude a 2D mesh to 3D. The 2D mesh has x,y,z coordinates, with z=0. The 3D mesh will have x,y,z coordinates. You need to specify in the initialisation part **number_of_space_dimensions** to 3.

With *z0*, *z1*, *z2* etc. you specify the coordinates of the layers to which the 2D coordinates will be extruded. With *n0*, *n1*, *n2* you specify the number of elements that will be generated in each layer; *n0* specifies the number of elements between *z0* and *z1*, *n1* specifies the number of elements between *z1* and *z2*, etc.; for the last *n*-value you always should use a 1 (this is a dummy value, that is not used for any layer at all).

Extrusion must be done before doing mesh refinements, mesh splitting, etc.

7.166 **control_mesh_extrude_direction** *index dir*

Default extrusion is done in the global z-direction. Optionally you can set *dir* to **-y** and then extrusion is done in global y-direction.

7.167 **control_mesh_extrude_element** *index name*

If you extrude **-tria6** elements, you can set *name* either to **-prism12** or **-prism18**. Then either the 12 node or 18 node prismatic elements will be generated. Default, if this **control_mesh_extrude_element** is not set, then **-prism18** is used for *name*.

See also **control_mesh_extrude_n** and optionally **control_mesh_extrude_element_group**.

7.168 **control_mesh_extrude_contact_spring_element_group** *index element_group_0 element_group_1 ...*

See **control_mesh_extrude_contact_spring_element_group_new**.

7.169 **control_mesh_extrude_contact_spring_element_group_new** *index element_group_new_0 element_group_new_1 ...*

If this record is specified, then a contact spring is generated between each start node and end node in the extrude direction. This option comes handy, when you want to use these contact springs to enforce that the nodes on the start plane get the same displacements as the nodes on the end plane, which models that the extruded mesh is in fact part of a very long domain with no variations in the longitudinal direction of the domain.

The contact springs get group number *element_group_new_0* when its node is attached to an element with old group *element_group_0*. The contact springs get group number *element_group_new_1* when its node is attached to an element with old group *element_group_1*. Etc. The old groups are specified in the **control_mesh_extrude_contact_spring_element_group** record. If the contact spring's node is attached to more than one old group, the first specified old group, and corresponding new group, will be used.

As a special option, if you specify in **control_mesh_extrude_contact_spring_element_group_new** only one new element group number, then all contact springs will be placed on that group.

7.170 **control_mesh_extrude_element_group** *index element_group_0 element_group_1 ... number_0 number_1 ...*

With this option you can limit the extrusion, if different parts of the mesh. More precise, you can set how much of the extrusion as specified by the **control_mesh_extrude** and **control_mesh_extrude_n** records will be done for elements from a specific **element_group**. This will result in a mesh which has different heights in different areas of the mesh.

The *element_group_0*, *element_group_1* etc. specify the element groups for which you want to limit the extrusion. The *number_0*, *number_1* etc. specify the the amount values of *n0*, *n1*, *n2*, that should be used for this specific element group. For example, if *element_group_0* is 6 and *number_0* is 2 then the elements belonging to element group 6 will only be extruded with *n0* and *n1*. The remaining *n2*, *n3*, will be put to 0 for these elements.

For element groups which are not restricted with this **control_mesh_extrude_element_group** record, all extrusion will be done (that is, all *n0*, *n1*, etc. will be used).

As a special option you can set the **group_type** of an element group in **control_mesh_extrude_element_group** to **-none**; then the mesh extrude will not generate the elements belonging to that group.

7.171 control_mesh_extrude_element_group_new *index element_group_old_0 element_group_old_1 ... element_group_new_00 element_group_new_01 ... element_group_new_11 ...*

With this option you set the `element_group` number of the new extruded elements.

With *element_group_old_0*, *element_group_old_1* etc. you specify the old `element_group` numbers of the 2D elements (which will be extruded). For these old groups, you specify for each layer in z-direction what the new `element_group` numbers of the extruded 3D elements should be. For example, *element_group_new_00*, *element_group_new_01* etc. give for *element_group_old_0* what the `element_group` numbers of the new extruded elements will be (for each z layer).

Attention: you need to specify `element_group` numbers for each and every z layer. So even if you actually limit the amount of z layers generated for a specific old group with the option **control_mesh_extrude_element_group**, you need to specify new group numbers for ALL layers (the new group numbers for non-generated new layers are in that case only dummy numbers).

Default, if an old `element_group` is not included in this **control_mesh_extrude_element_group_new** record, all new extruded elements will also get that same old `element_group` number.

See also **control_mesh_extrude**.

7.172 control_mesh_extrude_n *index n0 n1 n2 ...*

See **control_mesh_extrude**.

7.173 control_mesh_generate_beam *index element_group geometry_entity_item geometry_entity_index*

The same as **control_mesh_generate_truss**, now for beams however.

7.174 control_mesh_generate_contact_spring *index element_group geometry_entity_item geometry_entity_index*

Generate **-contact_spring2** springs for nodes which have the same position in space. This can be used to connect these nodes with spring elements, so to model a contact area. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the contact springs.

With the **control_mesh_generate_contact_spring_element** record you can set between which elements the contact_springs should be generated. For example use **-quad4** and **-truss_beam** if you want to generate contact_springs between those elements.

If **control_mesh_generate_contact_spring_element_group** (with the same index) is used, contact springs will only be generated between elements of the groups *element_group_0*, *element_group_1* etc.

7.175 `control_mesh_generate_contact_spring_element` *index element_0 element_1*

See `control_mesh_generate_contact_spring`.

7.176 `control_mesh_generate_contact_spring_element_group` *index element_group_0 element_group_1 ...*

See `control_mesh_generate_contact_spring`.

7.177 `control_mesh_generate_interface` *index element_group_0 element_group_00 element_group_01 element_group_1 element_group_10 element_group_11 ...*

With this record you can generate interface elements.

The interface elements will be given an **element_group** record *element_group_0* if the interface is between *element_group_00* and *element_group_01*. The interface elements will be given an **element_group** record *element_group_1* if the interface is between *element_group_10* and *element_group_11*. The interface elements will be given an **element_group** record *element_group_2* if the interface is between *element_group_20* and *element_group_21*. Etc, etc.

The groups *element_group_00*, *element_group_10*, *element_group_20*, etc. should be on one side. The groups *element_group_01*, *element_group_11*, *element_group_21*, etc. should be on the opposite side.

Between two linear 2d elements **-quad4** interfaces will be generated. Between two quadratic 2d elements **-quad6** interfaces will be generated. Between two **-hex8** elements a **-hex8** interface will be generated. Between two **-hex27** elements a **-quad18** interface will be generated. Between two **-tet4** elements a **-prism6** interface will be generated. Between two **-tet10** elements a **-tria12** interface will be generated. Between two **-prism6** elements a **-prism6** interface will be generated on sides with 3 nodes. Between two **-prism6** elements a **-hex8** interface will be generated on sides with 4 nodes. For other situations no interface element will be generated.

Crossing interfaces are not allowed, eg in 2d you should not have locally two connecting lines with interfaces and in 3d you should not have locally two connecting surfaces with interfaces.

Interfaces can only be generated between exactly two elements. You cannot generate interface where three elements connect; by example you cannot generate an interface at the common side of two quad4 elements if there is also a truss along that common side.

If you want the interface to connect, you really should do by example:

```
...
control_mesh_generate_interface 10 20 30 31 20 40 41
...
```

which takes care that the interfaces generated by this command are connected together. If you would have used the following:

```
...
control_mesh_generate_interface 10 20 30 31
control_mesh_generate_interface 11 20 40 41
```

...

The interfaces generated by the two commands will not connect.

See also **control_mesh_generate_interface_method**.

7.178 **control_mesh_generate_interface_method** *index method_select method_generate*

If you set *method_select* to **-element_geometry** the **control_mesh_generate_interface** will select with **element_geometry** between which elements interfaces will be generated.

If you set *method_generate* to **-element_geometry** the **control_mesh_generate_interface** will generate **element_geometry** records for the interface elements, in stead of **element_group** records.

So by example using **-element_geometry -element_geometry** tells that the **control_mesh_generate_interface** in fact is *index element_geometry_0 element_geometry_00 element_geometry_01 element_geometry_1 element_geometry_10 element_geometry_11 ...*

Default, if **control_mesh_generate_interface_method** is not specified, it is set to **-element_group -element_group**.

7.179 **control_mesh_generate_spring1** *index element_group geometry_entity_item geometry_entity_index*

Generate **-spring1** springs for nodes. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the springs (see **group_spring_stiffness** etc.).

7.180 **control_mesh_generate_spring2** *index element_group geometry_entity_item geometry_entity_index*

Generate **-spring2** springs for nodes which have the same position in space. This can be used to connect these nodes with spring elements. Only nodes located on the specified geometry entity will be used.

The generated springs will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the springs (see **group_spring_stiffness** etc.).

Typically you can use this option to connect meshes which were generated with different **control_mesh_macro** records or so.

If you need interfaces, then afterwards use a **control_mesh_convert** to turn the generated surface elements into real interface elements.

7.181 control_mesh_generate_truss *index element_group geometry_entity_item geometry_entity_index*

Generate trusses for nodes which are neighbor in space (that is, for nodes which are connected by an isoparametric finite element). Only nodes located on the specified geometry entity will be used.

The generated trusses will get an **element_group** record with value *element_group*. So in that element group you can put the properties of the trusses (see **group_truss_elasti_young** etc.).

Typically you can use this option to put easy trusses somewhere in a mesh with isoparametric elements.

7.182 control_mesh_generate_truss_beam *index element_group geometry_entity_item geometry_entity_index*

The same as **control_mesh_generate_truss**, now for truss_beams however.

7.183 control_mesh_generate_truss_beam_loose *index switch*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

If *switch* is set to **-yes**, the truss or beam of truss_beam will not be connected to the existing nodes, but new nodes will be generated for the generated element.

Afterwards you can typically connect the truss or beam of truss_beam to the existing mesh with **constactsprings**, so that the end result is that you can model frictional slip between isoparametric elements and structural elements.

See also **control_mesh_generate_contact_spring**.

7.184 control_mesh_generate_truss_beam_macro *index macro_0 macro_1 ...*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

With *macro_0* etc. you can specify the indices of **control_mesh_macro_*** records. Then the trusses (or beams or truss_beams) will only be generated for nodes coming from the mesh generated by the macro records with the specified indices.

This is handy in case you generate two neighboring meshes with macro's, and want to generate the elements (trusses or beams or truss_beams) in between these two meshes. Normally, both the meshes would get the extra truss (or ..) in case you use a **geometry_line** or so to specify that the new elements should be generated between the two meshes (this is so, since the nodes of both meshes are located on the **geometry_line**). With the present **control_mesh_generate_truss_beam_macro** record however you can specify that the new elements should only be generated by looking at the nodes of some of the meshes, and so no double new elements will be generated in between the two meshes.

7.185 **control_mesh_generate_truss_beam_separate** *index switch*

This record works together with the **control_mesh_generate_truss**, **control_mesh_generate_beam** and **control_mesh_generate_truss_beam** records.

If *switch* is set to **-yes**, the truss or beam of **truss_beam** will be generated for separate regions, not necessary connected by isoparametric finite elements.

A typical example is the generation of exactly one truss between two end points (thus no trusses along all of the isoparametric elements between the end points). For this, put the end points in a geometry set, and also use **-yes** for this **control_mesh_generate_truss_beam_separate** record.

7.186 **control_mesh_interface_triangle** *index switch*

See **mesh_interface_triangle_coordinates**.

7.187 **control_mesh_keep_element** *index element_0 element_1 ...*

With this option you can delete all elements except for the elements with numbers *element_0*, *element_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

7.188 **control_mesh_keep_element_group** *index element_group_0 element_group_1 ...*

With this option you can delete all elements except for the elements with group numbers *element_group_0*, *element_group_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

7.189 **control_mesh_keep_geometry** *index geometry_item_name geometry_item_index*

With this option you can delete all elements except for the elements present in the specified geometry. This enables you to clearly view some specific elements and nodes in a plot.

7.190 **control_mesh_keep_node** *index node_0 node_1 ...*

With this option you can delete all nodes except for the nodes with numbers *node_0*, *node_1*, etc. This enables you to clearly view some specific elements and nodes in a plot.

7.191 **control_mesh_macro** *index macro_item element_group n ...*

With this record and the **control_mesh_macro_parameters** record you define a macro region. The macro region will automatically be divided into finite elements.

The type of macro region is defined by *macro_item*. You can set *macro_item* to a **-sphere** (3D), **-cylinder** (3D), **-cylinder_hollow** (3D), **-brick** (3D), **-rectangle** (2D), **-circle** (2D), **-circle_hollow** (2D) and **-bar** (1D).

The elements to be generated will get **element_group** *element_group*.

With *n* ... you define how much nodes and elements will be generated. For a **-cylinder**, you need to specify the number of nodes in the length direction, the number of nodes in radial direction and the number of nodes in circ. direction (there is always only one element in radial direction). For a **-cylinder_hollow**, you need to specify the number of nodes in the length direction, the number of nodes over the wall thickness and the number of nodes in circ. direction. For a **-brick**, you need to specify the number of nodes in x-direction, the number of nodes in y-direction and the number of nodes in z-direction. For a **-circle** and **-sphere**, you need to specify 'fineness' of the mesh, which is a number 0, 1, 2, 3, ...; a higher number gives a higher fineness; typically use 3 or so. For a **-circle_hollow**, you need to specify the number of nodes over the wall thickness, the number of elements in tangential direction. For a **-rectangle**, you need to specify the number of nodes in first direction and the number of nodes in second direction. For a **-bar**, you need to specify the number of nodes.

In the following example a sphere is generated, after which the nodes get an initial velocity:

```
...
number_of_space_dimension 2
...
end_initia
...
control_mesh_macro 20 -sphere ...
control_mesh_macro_parameters 20 ...
...
control_data_put 30 -node_dof -all
control_data_put_double 30 0. 1. ...
...
```

7.192 control_mesh_macro_concentrate *index* ...

For the **-rectangle** macro you can specify with this **control_mesh_macro_concentrate** record a mesh fineness concentration factor in the first direction and in the second direction. In each direction give a mesh fineness factor at the beginning and at the end (so two factors per direction). A smaller factor means smaller elements. The relative size of the factor determines where elements are concentrated, at the start or at the end.

7.193 control_mesh_macro_element *index element_type*

With this option you can set the element type which will be generated with **control_mesh_macro** (with the same index). This option is only available in 2d and 3d.

For **element** you can use **-tria3**, **-tria6**, **-quad4** and **-quad9** in 2d. For **element** you can use **-tet4**, **-tet10**, **-hex8** and **-hex27** in 3d.

If this record is not specified then **-bar2** (1d), **-quad4** (2d) or **-hex8** (3d) will be generated.

Attention: in case you choose a quadratic element the macro geometry may not be exactly followed. In this case, leave the default linear elements, and use a global mesh refinement to quadratic elements afterwards, including the geometry to follow.

7.194 `control_mesh_macro_parameters` *index x y ...*

With this record you can specify the dimensions of the **control_mesh_macro** region.

For a **-sphere**, you need to specify the x, y, z coordinates of the middle of the sphere and the radius of the sphere. For a **-cylinder**, you need to specify the x, y, z coordinates at the start of the cylinder, the x, y, z coordinates at the end of the cylinder, the radius, the start angle and the end angle in degrees (which allows for an open section). For a **-cylinder_hollow**, you need to specify the x, y, z coordinates at the start of the cylinder, the x, y, z coordinates at the end of the cylinder, the middle radius, the wall thickness, the start angle and the end angle in degrees (which allows for an open section). For a **-brick**, you need to specify the x, y, z coordinates at the middle, the length in x-direction, the length in y-direction, and the length in z-direction. For a **-circle**, you need to specify the x, y coordinates of the middle and also the radius. For a **-circle_hollow**, you need to specify the same as for the **circle** and additionally the wall thickness, the start angle and the end angle in degrees (which allows for an open section). For a **-rectangle**, you need to specify the x, y coordinates of the middle, the width and the height respectively. For a **-bar**, you need to specify the x coordinate of the middle and the length respectively.

7.195 `control_mesh_map` *index switch*

A typical piece of input file is

```
...
global_element_dof_apply -no
...
... (input file with quadratic elements -hex20 or -hex27 or -tet10 or -prism15)
...
control_mesh_map ...-yes (map to linear elements -hex8 or -prism6 or -tet4)
...
control_timestep ... (calculate with linear elements)
control_solver ...-matrix_pardiso (with pardiso solver)
...
control_mesh_map -yes (map back to quadratic elements)
...
control_timestep ... (calculate with quadratic elements)
control_solver ...-matrix_iterative_bicg (with bicg solver)
...
```

In this way, the last calculation with the quadratic elements gets as first guess for the bicg solver the solution field of the linear elements with the pardiso solver. This saves much computing time for bicg, especially in very large calculations. This strategy normally should only be used for large linear calculations. For this option always set **global_element_dof_apply -no**.

7.196 `control_mesh_merge` *index switch*

If *switch* is set to **-yes**, then nodes with the same coordinates are merged into one node.

7.197 `control_mesh_merge_eps_coord` *index epsilon*

Distance below which nodes will be merged. Default some small value.

7.198 **control_mesh_merge_macro_generate** *index macro_0 ...*

This record works together with the **control_mesh_merge** record.

With *macro_0* etc. you can specify the indices of **control_mesh_macro_*** or **control_mesh_generate_*** records. Then the merging will only be done for nodes coming from the mesh generated by the macro or generate records with the specified indices.

7.199 **control_mesh_merge_geometry** *index geometry_entity_item geometry_entity_index*

The mesh merging from **control_mesh_merge**, with the same index, will only be used for nodes in the geometry specified by *geometry_entity_item geometry_entity_index*.

7.200 **control_mesh_merge_geometry_not** *index geometry_entity_item geometry_entity_index*

The mesh merging from **control_mesh_merge**, with the same index, will not be used for nodes in the geometry specified by *geometry_entity_item geometry_entity_index*.

7.201 **control_mesh_multiply** *index number_of_multiplications*

The mesh is multiplied *number_of_multiplications* times. In each multiplication the mesh gets double the amount of elements, because for each element a new element is generated with the same nodes.

7.202 **control_mesh_refine_globally** *index refinement_type*

This record activates global mesh refinement or global mesh coarsening. This is not available for **-tria3** and **-tet4** elements. Either *refinement_method* is **-h_refinement** (more of the same elements) or *refinement_method* is **-p_refinement** (higher order elements) or *refine_method* is **-p_coarsen** (lower order elements).

As a special option for the **-h_refinement** method, the format **refine_globally index -h_refinement switch_ξ switch_η switch_ζ** can be used. For example in 1D, only **refine_globally index -h_refinement switch_ξ** should be specified. For example in the **-hex8** element, ξ is the isoparametric coordinate running from the first node to the second node, η runs from the first node the third node and ζ runs from the first node to the fifth node. A isoparametric direction will be refined if the corresponding switch is set to **-yes**. This option allows for refinement in specific directions. It should be used with care however, and only gives proper results if the ξ, η and ζ directions of the elements match.

The **control_mesh_refine_globally** will automatically merge nodes which have the same position in space.

Rules for old and new:

- A new generated element inherits its data items from the old element it is generated from.
- If a new generated node is placed on an old element edge it inherits those data items of the old nodes on that old edge that have a property in common; then arbitrarily the data item of one of the old nodes is taken.

- If a new generated node is placed inside an old element it inherits those data items of the old nodes of that old element that have a property in common; then arbitrarily the data item of one of the old nodes is taken.
- For all new nodes the **node_dof** records are interpolated from the old element nodes **node_dof** records by using the old element interpolation functions.

See also **control_mesh_refine_globally_geometry**.

7.203 **control_mesh_refine_globally_geometry** *index geometry_entity_item geometry_entity_index*

This record can be used together with the **control_mesh_refine_globally** record with the same index. If all nodes of an element edge is part of the geometrical entity, the new generated nodes are also placed on that geometrical entity. This typically is used to follow curved edges of the domain.

The **control_mesh_refine_locally** will automatically merge nodes which have the same position in space.

7.204 **control_mesh_refine_locally** *index percentage*

An elements will be refined depending on the size of a solution variable. The solution variable can be chosen via **control_mesh_refine_locally_dof**.

The percentage of elements which will be refined is specified by *percentage*. Typically *percentage* is 10 or so.

This local mesh refinement is only available for **-bar2**, **-bar3**, **-tria3**, **-tria6**, **-tet4** and **-tet10** elements; there should be no other elements in the mesh.

See the rules for old and new at **control_mesh_refine_globally**.

7.205 **control_mesh_refine_locally_dof** *index dof*

With *dof* you can set which dof will be used for deciding if an element should be refined. The size of the doffield will be used.

Possibilities for *dof* are: **-materi_damage**, **-materi_displacement**, **-materi_plasti_kappa**, **-materi_plasti_kappa_shear**, **-materi_strain_elasti**, **-materi_strain_plasti**, **-materi_strain_total**, **-materi_stress**, **-materi_velocity**, **-materi_void_fraction** and

As a special option you can set *dof* to **-nothing**; then an element is refined always.

For finding localization zones (e.g. shear bands) choosing **-materi_strain_plasti** or **-materi_damage** seems to be most robust.

See also **control_mesh_refine_locally_geometry**.

7.206 `control_mesh_refine_locally_geometry` *index geometry_entity_item geometry_entity_index*

This record can be used together with the `control_mesh_refine_locally` record with the same index. If all nodes of an element edge is part of the geometrical entity, the new generated nodes are also placed on that geometrical entity. This typically is used to follow curved edges of the domain.

7.207 `control_mesh_refine_locally_minimal_size` *index minimal_size*

Element with minimal size below the specified *minimal_size* will not be refined. The minimal element size is defined as the largest node distance between nodes of the element. Default the minimal allowed size is 0.

7.208 `control_mesh_refine_locally_not` *index geometry_entity_0 geometry_entity_index_0*

The refinement as specified in the `control_mesh_refine_locally` record with the same index, will not be applied on the geometry specified by *geometry_entity_0 geometry_entity_index_0*.

7.209 `control_mesh_refine_locally_not_method` *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding `control_mesh_refine_locally_not` is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding `control_mesh_refine_locally_not` is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

7.210 `control_mesh_refine_locally_only` *index geometry_entity_0 geometry_entity_index_0*

The refinement as specified in the `control_mesh_refine_locally` record with the same index, will only be applied on the geometry specified by *geometry_entity_0 geometry_entity_index_0*.

7.211 `control_mesh_refine_locally_only_method` *index method*

Set *method* to **-all** or **-any**. If *method* is set to **-all**, then the corresponding `control_mesh_refine_locally_only` is applied to elements for which all nodes are inside the specified geometry. If *method* is set to **-any**, then the corresponding `control_mesh_refine_locally_only` is applied to elements for which any of the nodes is inside the specified geometry. Default *method* is **-all**.

7.212 `control_mesh_remove` *index element_group_0 element_group_1*

With this option you can remove elements of *element_group_0* if they are completely located inside a elements of group *element_group_1*.

7.213 `control_mesh_remove_geometry` *index geometry_item_name geometry_item_index*

With this record you can restrict to which geometry the `control_mesh_remove` will be applied.

7.214 **control_mesh_remove_frequency_timeinterval** *index timeinterval*

Similar to **control_print_frequency_timeinterval** but now working on **control_mesh_remove** records however. This option is convenient to save computer time.

7.215 **control_mesh_remove_frequency_timestep** *index timestep*

Similar to **control_print_frequency_timestep** but now working on **control_mesh_remove** records however. This option is convenient to save computer time.

7.216 **control_mesh_renumber** *index lowest_element lowest_node*

The element numbers are made strictly sequential starting from *lowest_element* and the node numbers are made strictly sequential starting from *lowest_node*. Beware using **control_renumber** in combination with, for example, node numbers in printing of **node_dof** records; use **post_point** records instead.

7.217 **control_mesh_renumber_element_geometry_offset** *index offset*

While renumbering elements the element geometry number will be offset with *offset*.

7.218 **control_mesh_renumber_element_group_offset** *index offset*

While renumbering elements the element group number will be offset with *offset*.

7.219 **control_mesh_rotate** *index n*

After rotation *n* is the number of elements in rotational direction for a rotation over 360 degrees. After rotation the old *y* direction becomes the new *z* direction. The following data is transferred in the rotation process: **element**, **element_group**, **node** and **node_dof**. A 2D **-tria3** element becomes a 3D **-prism6** element and a 2D **-quad4** element becomes a 3D **-hex8** element; other 2D elements can presently not be rotated. All data that is not valid in 3D, like for example a 2D line etc, will be deleted in the rotation process.

This **control_mesh_rotate** is convenient when the first part of calculation is axisymmetric, for example loading a pile vertically in a soil, and the second part of the calculation is 3D, for example loading the top of the pile in some horizontal direction. Then first an axis-symmetric calculation can be performed, and the results can be used to start a 3D calculation.

If a **-quad4** elements has a side on the *y*-axis in the 2D mesh, the element is rotated to a **-prism6** element; the **-quad4** element should have the side with local node numbers 0 and 1 on the *y*-axis, which is the case if you generated the elements with a **control_mesh_macro**. You should not use other elements with a side on the *y*-axis when rotating the mesh.

This **control_mesh_rotate** deletes all data, except **element**, **element_group**, **node**, **node_dof**, **element_interface_strain** and **element_interface_stress** will be rotated to 3D. Furthermore, **control_input** will be available afterwards, so that all 3d data can be set in an extra input file, which is read after the mesh rotation.

If you use any history variables in the model, these should be scalars (and thus not vectors or matrices); otherwise rotation will not go ok for the history variables.

7.220 **control_mesh_rotate_angle** *index angle*

With *angle* you can specify an angle in degrees up to which the mesh rotation should be done for the **control_mesh_rotate** with the same index. Typically you could use 90 degrees or 180 degrees for *angle*. Default, if this **control_mesh_rotate_angle** is not specified, *angle* will be set to 360.

7.221 **control_mesh_split** *index switch*

If *switch* is set to **-yes** then each **-quad4** element is split into four **-tria3** elements and each **-hex8** element is split into twelve **-tet4** elements. Further, each **-quad9** element is split into four **-tria6** elements and each **-hex27** element is split into six **-tet10** elements. Further, each **-tria6** element is split into four **-tria3** elements.

See the rules for old and new at **control_mesh_refine_globally**. See also **control_mesh_split_element_to**, and **control_mesh_split_only**.

Splitting a 3D mesh will only work correctly on certain regular grids; you need to check the splitted mesh.

7.222 **control_mesh_split_element_from** *index name*

Split only elements with the specified *name*.

7.223 **control_mesh_split_element_to** *index name*

If you are splitting **-hex8** elements, then you can set **name** either to **-tet4** or **-prism6**. Default, if **control_mesh_split_element_to** is not specified, **-tet4** is used.

If you are splitting **-hex27** elements, then you can set **name** either to **-tet10** or **-prism18**. Default, if **control_mesh_split_element_to** is not specified, **-tet10** is used.

7.224 **control_mesh_split_only** *index geometry_entity geometry_entity_index*

If this record is used, the corresponding **control_mesh_split** record will only be applied on elements which have at least one node on the geometry specified by *index geometry_entity_name geometry_entity_index*.

7.225 **control_mesh_truss_distribute_mpc** *index switch*

If *switch* is set to **-yes** the nodes of truss elements are fixed with multi point constraints (mpc's) to the isoparametric elements through which the trusses run. This typically can be used for modeling reinforcement bars in a concrete embedment, where the bars follow the displacements (and temperatures if present) of the concrete.

If **control_mesh_truss_distribute_mpc_exact** *switch* is set to **-yes**, truss elements are redistributed (that is, more small truss elements will be made), in such way that each truss gets a node when it enters an isoparametric element or ends internally in an isoparametric element. This **control_mesh_truss_distribute_mpc_exact** comes handy when you initially have large trusses relative to the isoparametric elements.

Truss below a minimum length as specified in **control_mesh_truss_distribute_mpc_exact_minimal_length** will not be generated; default the minimal length *tolerance* is set to some small value. With **control_mesh_truss_distribute_mpc_exact_minimal_length_connect** you can determine if the generated trusses jumping a space below the minimal length will be connected or will be not-connected (loose); set the *switch* to **-yes** if you want the truss to be connected in such case. Please realise that the connection is ensured only for the trusses generated from 1 old truss; connection is not ensured for trusses generated from different old truss elements.

This **control_mesh_truss_distribute_mpc** option is done for truss groups as specified in **control_mesh_truss_distribute_mpc_element_group_truss** or in **control_mesh_truss_distribute_mpc_geometry_truss**.

Only one of **control_mesh_truss_distribute_mpc_element_group_truss** and **control_mesh_truss_distribute_mpc_geometry_truss** can be specified.

If none of **control_mesh_truss_distribute_mpc_element_group_truss** and **control_mesh_truss_distribute_mpc_geometry_truss** is specified the distribution will be done for all trusses.

Default Tochnog will look for all isoparametric elements how to distribute the trusses. To save computer time you can restrict the geometry or element group of the isoparametric elements where Tochnog will look with **control_mesh_truss_distribute_mpc_element_group_isoparametric** and **control_mesh_truss_distribute_mpc_geometry_isoparametric**.

Please notice that if you are using geometries in **control_mesh_truss_distribute_mpc_geometry_truss** or **control_mesh_truss_distribute_mpc_geometry_isoparametric** these can in fact be a **geometry_set**.

In case you specify both of the above ***_truss** and ***_isoparametric**, the number of specified values (groups or geometries) should be the same. Then the first value specified for the truss will be combined with the first value specified for the isoparametric elements, the second value specified for the truss will be combined with the second value specified for the isoparametric elements, etc. By example, if you specify two groups for **control_mesh_truss_distribute_mpc_element_group_truss** and

two groups for **control_mesh_truss_distribute_mpc_element_group_isoparametric** the first specified truss group will be distributed over the first specified isoparametric group, and the second specified truss group will be distributed over the first specified isoparametric group.

If *switch* in **control_mesh_truss_distribute_mpc_air** is set to **-yes**, trusses will also be generated in the center of the truss is not inside an isoparametric element. If *switch* in **control_mesh_truss_distribute_mpc** is set to **-no**, trusses will not be generated in the center of the truss is not inside an isoparametric element. Default *switch* is **-yes**.

A typical input file looks like:

```
control_mesh_truss_distribute_mpc 10 -yes
control_mesh_truss_distribute_mpc_exact 10 -yes
control_mesh_truss_distribute_mpc_geometry 10 -element_geometry 123
```

Only one **control_mesh_truss_distribute_mpc** record is allowed in the input file. As a special option you can also generate **truss_beam** elements in stead of **truss** elements.

7.226 **control_mesh_truss_distribute_mpc_air** *index switch*

See **control_mesh_truss_distribute_mpc**.

7.227 **control_mesh_truss_distribute_mpc_dof** *dof_0 dof_1 ...*

The *dof_0 dof_1 ...* specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc.

7.228 **control_mesh_truss_distribute_mpc_element_group_truss** *index element_group_0 element_group_1 ...*

See **control_mesh_truss_distribute_mpc**.

7.229 **control_mesh_truss_distribute_mpc_element_group_isoparametric** *index element_group_0 element_group_1 ...*

See **control_mesh_truss_distribute_mpc**.

7.230 **control_mesh_truss_distribute_mpc_exact** *index switch*

See **control_mesh_truss_distribute_mpc**.

7.231 **control_mesh_truss_distribute_mpc_exact_minimal_length** *index tolerance*

See **control_mesh_truss_distribute_mpc**.

7.232 **control_mesh_truss_distribute_mpc_exact_minimal_length_connect** *index switch*

See **control_mesh_truss_distribute_mpc**.

7.233 **control_mesh_truss_distribute_mpc_geometry_truss** *index geometry_entity_name geometry_entity_index_0 geometry_entity_name_1 geometry_entity_index_1 ...*

See **control_mesh_truss_distribute_mpc**.

7.234 `control_mesh_truss_distribute_mpc_geometry_isoparametric` *index geometry_entity_name_0 geometry_entity_index_0 geometry_entity_name_1 geometry_entity_index_1 ...*

See `control_mesh_truss_distribute_mpc`.

7.235 `control_mpc_element_group` *index switch*

If *switch* is set to **-yes** the `mpc_element_group` records will be evaluated at all timesteps for the current control index. If *switch* is set to **-no** the `mpc_element_group` records will only be evaluated when the mesh has been changed.

Default, if `control_mpc_element_group` is not specified, the *switch* is set to **-no**.

7.236 `control_mpc_element_group_frequency_timeinterval` *index timeinterval*

Similar to `control_print_frequency_timeinterval` but now working on `control_mpc_element_group` records however. This option is convenient to save computer time.

7.237 `control_mpc_element_group_frequency_timestep` *index timestep*

Similar to `control_print_frequency_timestep` but now working on `control_mpc_element_group` records however. This option is convenient to save computer time.

7.238 `control_plasti_apply` *index switch*

If *switch* is set to **-no**, any plasticity data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with plasticity data. See also `plasti_apply`.

7.239 `control_post` *index switch*

You can save cpu time in timesteps with the same index by setting *switch* to **-no**, which prevents `post_calcul` commands to be evaluated in these timesteps.

7.240 `control_post_element_force` *index switch*

You can save cpu time in timesteps with the same index by setting *switch* to **-no**, which prevents `post_element_force` commands to be evaluated in these timesteps.

7.241 **control_print** *index data_item_name_0 data_item_name_1 ...*

This is the normal printing command. A **control_print** record causes the data items with name *data_item_name_0*, etc. to be printed. Example

```
control_print 1 -node -node_dof
```

See also: **print_filter**.

7.242 **control_print_beam_force_moment** *index switch*

This option prints the beam forces and moments through a set of beams starting at place x_{start} , y_{start} , z_{start} and ending at x_{end} , y_{end} , z_{end} as specified in **control_print_beam_force_moment_coordinates**. In 2D only x and y coordinates need to be specified. The forces and moments are printed in the file `beam_force_moment.index`. In fact, if the element contains a truss (either a truss element or a truss-beam element), the truss force will be used for the axial force. The first column in the file is the distance from the start point. The following columns contain in the local beam axes `force_x_first_node` `force_y_first_node` `force_z_first_node` `moment_x_first_node` `moment_y_first_node` `moment_z_first_node` `force_x_second_node` `force_y_second_node` `force_z_second_node` `moment_x_second_node` `moment_y_second_node` `moment_z_second_node`. The *switch* needs to be set to **-separate_index** or **-separate_sequential**. See also **control_print_beam_force_moment_switch**.

7.243 **control_print_beam_force_moment_coordinates** *index x_start y_start z_start x_end y_end z_end*

See **control_print_beam_force_moment**.

7.244 **control_print_beam_force_moment_switch** *index switch*

If you set *switch* to **-yes**, the definition of the beam forces and moments is changed (multiplied with a -1). So you can get exactly the definition that you want.

7.245 **control_print_database** *index switch*

If *switch* is set to **-separate_index**, the complete database is printed. See the example below

```
control_print_database 6 -separate_index
```

This database contains the complete status of the calculation. For example if *index* is 6, the database is printed in the file `input_file_name6.dbs`. As a special option, you can print databases with sequential numbers by setting *switch* to **-separate_sequential**.

If tochnog exists with an error, for example due to non-convergence, a complete database is printed in `input_file_name_error.dbs`. Otherwise, a complete database will be printed at the end of the calculation.

7.246 **control_print_database_method** *index method*

If *method* is set to **-all** then all database base records will be printed in the database. If *method* is set to **-size_tot** then the size of all database base records will be printed in the database. If *method* is set to **-size_tot_large** then the size of database base records larger than 1 Mb will be printed in the database.

When using **-size_tot** or **-size_tot_large** also the size of the system matrix is printed in the database.

Default, if **control_print_database_method** is not specified, the *method* is set to **-all**.

7.247 **control_print_data_versus_data** *index data_item_name_0 index_0 number_0 data_item_name_1 index_1 number_1 ...*

This option prints columns of data for each time step. Print in the first column the *number_0* value of *data_item_name_0* with index *index_0*. Similar in the second column for *data_item_name_1* *index_1* *number_1*. Etc. (for all values). All results will be printed in the file *problemname.dvd*.

Typically, the data item names can be **-node_dof** such that dof's can be printed against each other in time. If the data item names are **-node_dof**, then *number_0* and *number_1*, etc. can be names of **dof_label** (eg **-velx**).

Also typically, the data item names can be **-node_dof_calcul** such that post calculation results can be printed against each other in time. If the data item names are **-node_dof_calcul** or **post_point_dof_calcul** or so, then *number_0* and *number_1*, etc. can be names of **post_calcul_label** (eg **-aept**).

Otherwise, for example, if *number_0* is 3 then the fourth value of *data_item_name_0* is printed.

Example:

```
control_print_data_versus_data 0 -node_dof 2 -temp  
-node_dof 2 -sigxx -node_dof 2 -sigxx
```

Another example:

```
post_point 0 0.0 1.0  
post_calcul -materi_stress -average -materi_stress -size_dev  
  
control_print_data_versus_data 20  
-time_current 0 0  
-post_point_dof_calcul 0 0 -post_point_dof_calcul 0 1
```

In the last example, the **-post_point_dof_calcul 0 0** stands for 'the **post_point_dof_record** with index 0 and the 0'th number which is the first value so the average of the stresses'.

For data that is not present Tochnog will print a 0.

See also: **control_print**.

7.248 `control_print_dof` *index switch*

Results for the primary dof's will be printed, including also the coordinates at which the results hold. Also results for **node_dof_calcul** records will be printed. The printed files will contain lines like x , y , z and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only x will be printed, etc.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

7.249 `control_print_dof_line` *index switch*

This **control_print_dof_line** record together with the **control_print_dof_line.coordinates** and **control_print_dof_line.n** records print values of the **node_dof** records and **node_dof_calcul** records along a line in space to files.

The start point of the first line segment is given by x_0 y_0 z_0 , and the end point of the first line segment is given by x_1 y_1 z_1 , the start point of the second line segment is given by x_1 y_1 z_1 , and the end point of the second line segment is given by x_2 y_2 z_2 , etc.

In 1D only the x-coordinates of the start point and end point need to be specified, etc. The parameter *n* determines how many points will be printed along the line.

The printed files will contain lines like x , y , z and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only x will be printed, etc.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

In **control_print_dof_line.method** you can set *node_type* either to **-node** or **-node_start_refined**. Then the coordinates in the printed file will contain either the values of **node** or the values of **node_start_refined**. In case you use an updated lagrange formulation where the mesh nodes follow the material the values of **node** and **node_start_refined** will differ; in case you do a geometrically linear analysis the values will not differ. Default *node_type* is set to **-node_start_refined**.

7.250 `control_print_dof_line_coordinates` *index* x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 ...

See **control_print_dof_line**.

7.251 `control_print_dof_line_method` *index node_type*

See **control_print_dof_line**.

7.252 `control_print_dof_line_n` *index n*

See **control_print_dof_line**.

7.253 `control_print_dof_line_time` *index switch*

If *switch* is set to **-yes** the first line of each file will specify the **time_current** at which the file is written (in gnuplot comment format).

7.254 `control_print_dof_point` *index switch*

This **control_print_dof_point** record prints values of the **node_dof** records and **node_dof_calcul** records in a point in space to files.

The point is given by $x\ y\ z$,

In 1D only the x-coordinates of the start point and end point need to be specified, etc.

The printed files will contain lines like x , y , z and *dof* (where *dof* is the dof, e.g. **temp**). In 1D only x will be printed, etc.

If *switch* is set to **-separate_index** the filenames will be like *dof.index*.

If *switch* is set to **-separate_sequential** then the filenames will be sequentially numbered, like *dof.0*, *dof.1*, etc.

7.255 `control_print_dof_point_coordinates` *index x y z*

See **control_print_dof_line**.

7.256 `control_print_dof_point_time` *index switch*

If *switch* is set to **-yes** the first line of each file will specify the **time_current** at which the file is written (in gnuplot comment format).

7.257 `control_print_dof_rhside` *index switch*

If *switch* is set to **-yes** then results for right-hand-side for the primary dof's will be printed, including also the coordinates at which the results hold.

For example, for the file *temp_rhside.index* will contain lines containing x , y , z and right-hand-side of **-temp** (that is, heat flux). In 1D only x will be printed, etc.

7.258 `control_print_element` *index data_item_name*

With this option you can print values from element data versus coordinates. Select either **-element_truss_force** or **-element_beam_force_moment** for *data_item_name*.

The normal truss forces of the **-element_truss_force** records will be printed in the file **element_truss_force_n.index**. This file will contain lines containing x , y , z and normal truss force. In 1D only x will be printed, etc.

The lateral beam shear forces of the **-element_beam_force_moment** records will be printed in the file **element_beam_force_moment_q.index**. This file will contain lines containing x , y , z

and lateral beam shear force. In 1D only x will be printed, etc. The shear force will always be calculated as an absolute value.

The beam moments of the **-element_beam_force_moment** records will be printed in the file **element_beam_force_moment_m.index**. This file will contain lines containing x , y , z and beam moment. In 1D only x will be printed, etc.

How the data is printed depends on how *method* is set in **control_print_element_method**. If method is set to **-middle** then only the average value of the element data and the coordinate of the middle of the element is printed for each element. If method is set to **-node** then the two nodal values and nodal coordinates are printed for each element.

7.259 control_print_element_method *index method*

Set *method* to **-middle** or **-node**. If **control_print_element_method** is not specified then **-middle** is used. See also **control_print_element**.

7.260 control_print_filter *index print_filter_index_0 print_filter_index_1 ...*

See **print_filter**.

7.261 control_print_frequency_timeinterval *index timeinterval*

This **control_print_frequency_timeinterval** record causes **control_print_gid**, **control_print_tecplot**, etc. to be done each time after a time interval has passed, and always also at the end of the time increment. This **control_print_frequency_timeinterval** record should only be used in combination with **control_timestep** (with the same index). All **control_print_*** printing will be influenced except **control_print**, **control_print_history** and **control_print_data_versus_data** printing.

Example:

```
control_timestep 10 0.04 0.41
control_print_gid 10 -yes
control_print_frequency_timeinterval 10 0.15
```

In this example gid data is written at times 0.16, 0.32, 0.41

7.262 control_print_frequency_timestep *index timestep*

This **control_print_frequency_timestep** record causes **control_print_gid**, **control_print_tecplot**, etc. to be done each time after a number of time timesteps has passed, and always also at the end of the time increment. This **control_print_frequency_interval** record should only be used in combination with **control_timestep** (with the same index). All **control_print_*** printing will be influenced except **control_print**, **control_print_history** and **control_print_data_versus_data** printing.

Example:

```

control_timestep 10 0.04 0.41
control_print_gid 10 -yes
control_print_frequency_timestep 10 5

```

In this example gid data is written at times 0.20, 0.40, 0.41

7.263 control_print_gid *index switch*

Print the mesh and the dof's in a file which can be plotted with the GID pre-post processor if *switch* is set to **-yes**. For example, if the input file is called turbine.dat then the mesh is written in the turbine.flavia.msh file. The results are written in the turbine.flavia.res.

The mesh and results for dof's will always be written at the end of the calculation.

Since GID gets confused when the number of elements changes between several **control_print_gid** records, Tochnog will only print GID results for the last mesh used.

Prism elements that GID cannot plot will be splitted by Tochnog into tet elements, depending on **control_print_gid_old**.

Coordinates for nodes will be written in the original configuration. If **materi_velocity** is initialized, also a vector **materi_mesh_deform** will be written for GID which contains the deformation between the original mesh configuration and the deformed mesh configuration. Use the **deform mesh** menu in GID, to draw the deformed configuration by applying the vector **materi_mesh_deform** with a factor 1.

For 2D interface elements which have strains and stresses, the normal stress **interface_sign**, the tangential shear stress **interface_sigt**, the normal strain **interface_epsn** and the tangential shear strain **interface_epst**, are written to the GID results file.

The following data is written also to the gid file and can serve as a help to check the validity of your input file. This data is only available after one or more time steps are taken.

- **condif_bounda_dof**, boundary conditions on temperature.
- **condif_heat_edge_normal**, distributed prescribed heat flow on an edge.
- **condif_convection_edge_normal**, distributed convection heat flow on an edge.
- **condif_radiation_edge_normal**, distributed convection heat flow on an edge.
- **groundflow_bounda_dof**, boundary conditions on groundflow hydraulic head.
- **materi_bounda_force**, discrete forces on nodes.
- **materi_force_edge**, distributed forces on nodes.
- **materi_force_edge_normal**, distributed normal forces on nodes.
- **materi_force_edge_projected**, distributed projected forces on nodes.
- **materi_force_edge_water**, distributed water forces on nodes.
- **materi_force_volume**, distributed volume forces on nodes.
- **materi_force_gravity**, distributed gravity forces on nodes.
- **materi_bounda_dof**, boundary conditions on materi velocity on nodes.

- **materi_support_edge_normal**, distributed support forces on nodes.
- **materi_rhside_free**, unbalance forces for **materi_velocity** (for free displacements) on nodex.
- **materi_rhside_fixed**, reaction forces for **materi_velocity** (for fixed displacements) on nodex.
- **element_materi_force_edge**, norm of distributed forces on elements.
- **element_materi_force_edge_normal**, norm of distributed normal forces on an edge on elements.
- **element_materi_force_edge_water**, norm of distributed water forces on an edge on elements.
- **plasti_reduction_factor**, reduction factor for plasticity parameters from **group_materi_plasti_element** etc.

If you have specified **print_node_geometry_present** then the gid files will contain **geometry...** values which are 1 on nodes present in a geometry.

The **materi_bounda_dof** you can view in gid with **View results, Display vectors, materi_bounda_dof, All**. The other data you can view in GID for example with **View results, Display vectors, force edge normal, | force edge normal |** . Above with 'distributed' we mean that results are per unit area.

For isoparametric elements the element group number will be printed.

As a special option, you can set *switch* to **-separate_index**. Then the mesh and results will be printed in separate files for GID, numbered with *index*. The option comes handy when the mesh changes during the calculation; GID cannot plot that if the mesh and results are in the same file.

As a further special option, you can set *switch* to **-separate_sequential**. Then the mesh and results will be printed in separate files for GID, number sequentially.

7.264 control_print_gid_beam_vectors *index switch*

If *switch* is set to **-yes**, force and moment vectors will be plotted for **-beam** and **-truss_beam** elements. The force and moment vectors will be plotted perpendicular to the length direction and a user specified plane-normal vector, see **control_print_gid_beam_vectors_normal**. The length of the plotted vectors measures the size of the forces and moment.

The vectors will be plotted as element result, so not as nodally averaged result.

Attention: this **control_print_gid_beam_vectors** is a special plotting option, to get each beam force and moment result as vector plot, with the possibility to influence the direction of the vectors with **control_print_gid_beam_vectors_normal**. Default Tochnog plots the beam result already as scalar values for each beam element.

7.265 control_print_gid_beam_vectors_normal *index normal_x normal_y normal_z*

This record gives you the possibility to influence the plane in which the moment vectors generated by the **control_print_gid_beam_vectors** will be plotted. In fact this **control_print_gid_beam_vectors_normal** specifies the normal to the plotting plane. If this **control_print_gid_beam_vectors_normal** is not specified then **0 0 1** is taken as normal.

7.266 **control_print_gid_contact_spring2** *index number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **contact_spring2** with two nodes, and to 1 if you want to draw **contact_spring2** with one node. Default, if **control_print_gid_contact_spring2** is not specified, then 1 node is used.

7.267 **control_print_gid_coord** *index switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in gid. If *switch* is set to **-no** the coordinates of nodes is not plotted in gid. Default *switch* is set to **-yes**.

7.268 **control_print_gid_dof** *index initialisation_name_0 initialisation_name_1 ...*

When you specify this record only the solution fields *initialisation_name_0*, *initialisation_name_1* etc will be printed to the gid files. So the files become smaller in size. This is especially convenient for very large calculations. The names *initialisation_name_0*, *initialisation_name_1* are names from the initialisation part like **-condif.temperature**, **-materi.velocity**, **-materi.stress** etc. In case you do not want any field to be printed in the gid file use **control_print_dof index -none**.

See also **control_print_gid_other**.

7.269 **control_print_gid_dof.calcul** *index calcul_0 calcul_1 ...*

When you specify this record only the post fields *calcul_0*, *calcul_1* etc will be printed to the gid files. So the files become smaller in size. This is especially convenient for very large calculations. See **post.calcul_label** for the allowed names of *calcul_0*, *calcul_1* etc. In case you do not want any post field to be printed in the gid file use **control_print_dof.calcul index -none**.

See also **control_print_gid_other**.

7.270 **control_print_gid_element_group** *index element_group_0 element_group_1 ...*

Select specific element groups for the gid files. If this record is not specified all element groups will be used.

7.271 **control_print_gid_empty** *index switch*

If *switch* is set to **-yes**, empty elements will be show in GID plots. If *switch* is set to **-no**, empty elements will not be shown. Default *switch* is set to **-no**.

See also **element_empty**.

7.272 **control_print_gid_mesh_activate_gravity** *index switch*

See also **mesh_activate_gravity_time**.

7.273 `control_print_gid_method` *index method*

If *method* is set to **-node**, results will be written for global nodes to the gid files. Gid will interpolate between the nodes, to fill contour plots, etc. Hence, you get continuous plots fields.

If *method* is set to **-element**, results will be written element-by-element to the gid files, so that any discontinuity in fields can be seen.

If *method* is set to **-node_elemen**, results will be written with continuous fields to the gid files, but at group jumps discontinuous fields are allowed.

For **-element** and **-node_elemen** gid cannot plot some results like 'contour fill' for all elements if there are several type of elements (quad4, tria3, ...) in the mesh. You can only select on specific element type for the plot.

If this `control_print_gid_method` record is not specified then *method* is set to **-node**.

7.274 `control_print_gid_old` *index switch*

If *switch* is set to **-yes** prism's will be plotted as tet's in GID. If *switch* is set to **-no** prism's will be plotted as prism's in GID when possible. Default, if *switch* is not specified, *switch* is set to **-no**

7.275 `control_print_gid_other` *index switch*

If *switch* is set to **-yes** also other things like boundary conditions, mesh deformation etc. are printed in the gid files. If *switch* is set to **-no** these other things are not printed in the gid files. Default *switch* is set to **-yes**.

7.276 `control_print_gid_save_difference` *index switch*

If *switch* is set to **-yes** then data differences relative to a saved status will be plotted. See `control_data_save`.

7.277 `control_print_gid_safety_slip_critical` *index switch*

If *switch* is set to **-yes**, then for a safety analysis with `control_safety_slip` only the critical slip surface will be plotted. Default, if *switch* is not set, all evaluated slip surfaces will be plotted. The critical surface is either determined over all safety surfaces, or otherwise in case sets are specified a critical surface is determined for each set.

Furthermore, always the normal stresses and shear stresses on the slip surfaces will be plotted.

7.278 `control_print_gid_spring2` *index number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw `spring2` with two nodes, and to 1 if you want to draw `spring2` with one node. Default, if `control_print_gid_spring2` is not specified, then `print_gid_spring2` is used.

7.279 `control_print_gid_truss_vector` *index switch*

Same as `control_print_gid_beam_vector`, however now for the normal force in `-truss` and `-truss_beam` elements.

Attention: this `control_print_gid_truss_vector` is a special plotting option, to get the truss force result as vector plot, with the possibility to influence the direction of the vectors with `control_print_gid_truss_vector_normal`. Default Tochnog plots the truss force result already as scalar values for each truss element.

7.280 `control_print_gid_truss_vector_normal` *index normal_x normal_y normal_z*

Same as `control_print_gid_beam_vectors_normal`, however now for the normal force in `-truss` and `-truss_beam` elements.

7.281 `control_print_gmsh` *index switch*

We discuss as an example the printed file naming convention if the input file name is `excavation.dat`

If *switch* is set to `-yes` the results are printed into the `excavation.msh` file. In case the mesh (elements and nodes) have not been printed before in this file, the file will be emptied, and the mesh will be printed. This will also be done if the mesh is changed.

If *index* is 100 and *switch* is set to `-separate_index` then the mesh and results are printed in the file is `excavation_100.msh`.

If *switch* is set to `-separate_sequential` then the mesh and results are printed in the files `excavation_0.msh`, `excavation_1.msh`, etc. So each time that a `control_print_gmsh` with `-separate_sequential` is evaluated a new file is generated with number increased by one.

A dummy point element is put in each node in the gmsh file. Gmsh needs that for plotting vector fields in the nodes. The dummy element group 1234 is used for these dummy point elements. You can suppress these dummy point elements by setting `control_print_gmsh_dummy` to `-no`.

All element data starts with `element_` in the plots. All node data starts with `node_` in the plots.

Scalar data with more then one value is given the extension `_0`, `_1` etc. for each of the values. By example the record `node` (which contains coordinates in each space direction) is plotted as scalar `node_0`, `node_1` and `node_2` which contain the x-coordinate, y-coordinate and z-coordinate respectively. By example the record `group_groundflow_permeability` (which contains permeability in each space direction) is plotted as scalar `group_groundflow_0`, `group_groundflow_1` and `group_groundflow_2` which contain the x-permeability, y-permeability and z-permeability respectively.

For nodes the presence in geometries is plotted as `node_geometry_*`. For elements the presence in geometries is plotted as `element_geometry_*`.

You can plot this file with the program `gmsh` ; see <http://www.geuz.org/gmsh> .

See also `input_gmsh`.

7.282 `control_print_gmsh_deformed_mesh` *index switch*

If *switch* is set to **-yes** the deformed mesh is printed in the gmsh file. If *switch* is set to **-no** the initial mesh is printed in the gmsh file. Default *switch* is set to **-no**.

7.283 `control_print_gmsh_dummy` *index switch*

See `control_print_gmsh`.

Default, if this record is not set and `print_gmsh_dummy` is not specified, *switch* is set **-yes**.

7.284 `control_print_gmsh_element_data` *index switch*

If you set *switch* to **-yes** data for elements (like element strains, stresses, etc.) is written averaged over the element; this corresponds to **ElementData** in the gmsh format.

If you set *switch* to **-no** this data is written for all element nodes; this corresponds to **ElementNodeData** in the gmsh format.

Default, if this record is not set, *switch* is set **-yes**.

7.285 `control_print_history` *index data_item_name_0 data_item_index_0 number_0 ...*

Print the time history for each of the sets *data_item_name_0 data_item_index_0 number_0 ...*

For example, if **-node_dof** is used, *number_0* is one of the names of **dof_label** (eg **-velx**).

For example, if **-node_dof_calcul** is used, *number_0* is one of the names of **post_calcul_label** (eg **-aept**).

Otherwise, *number_0* should be an integer specifying the number of the value in the record (for instance number 2 means the third value).

The following history is printed in the file `node_dof_112.temp.his`

```
control_print_history 0 -node_dof 112 -temp
```

7.286 `control_print_interface_stress` *index switch*

2D analysis

This option prints in 2D the interface stresses through a set of interfaces starting at place x_{start} , y_{start} and ending at x_{end} , y_{end} as specified in `control_print_interface_stress_coordinates`. The *switch* needs to be set to **-separate_index** or **-separate_sequential**. The stresses are printed in the file `interface_stress.index`. The first column in the file is the distance from the start point. The following columns contain `interface_sign` and `interface_sigt`. A line is written for each node of each interface element. Crossing interfaces are not allowed. From the start point up to the end point the interfaces need to be connected without gaps.

3D analysis

This option prints in 3D the average interface stresses in the middle of interface elements. The *switch* needs to be set to **-separate_index** or **-separate_sequential**. The interface element middles and average stresses are printed in the file `interface_stress.index`. The first three columns in the file are the coordinates of the middle of the interface element. The following columns contain `interface_sign` and `interface_sigt1` and `interface_sigt2`. A line is written for each interface element. If you specify **control_print_interface_stress_3d_geometry** then only interfaces elements located on the geometry will be printed. If you don't specify **control_print_interface_stress_3d_geometry** then all interfaces elements will be printed. You can specify the order of printing of the interfaces in the file with *method* in **control_print_interface_stress_3d_order**. If you set *order* to **-x** the interfaces will be ordered according to x-coordinate. If you set *order* to **-y** the interfaces will be ordered according to y-coordinate. If you set *order* to **-z** the interfaces will be ordered according to z-coordinate. If you don't use **control_print_interface_stress_3d_order** the interfaces will be ordered according to element number.

7.287 control_print_interface_stress_2d_coordinates *index x_start y_start x_end y_end*

For 2D only. See **control_print_interface_stress**.

7.288 control_print_interface_stress_3d_geometry *index geometry_item_name geometry_item_index*

For 3D only. See **control_print_interface_stress**.

7.289 control_print_interface_stress_3d_order *index order*

For 3D only. See **control_print_interface_stress**.

7.290 control_print_materi_stress_force *index method*

This option prints forces and moments as calculated by **post_calcul_materi_stress_force**. It prints in special purpose ascii files, convenient for further external postprocessing. By example, the name of the file will be **materi_stress_force.100** if the *index* is 100. The files themselves will contain comments explaining the detailed structure of the files.

The *method* can be set either to **-all** if all results should be printed in the file (so including the averaged results) or to **-primary** if only the primarily calculated results should be printed in the file (so not including the averaged results).

7.291 control_print_mesh_dof *index switch*

See **print_mesh_dof**.

7.292 **control_print_node** *index data_item_name number_0 number_1 ...*

With this record you can print nodal data like **node_dof**, **node_dof_calcul** etc. to files. As an example in 2D you can use **control_print_node index -node_dof -velx -velx** to get the files **velx.index** and **vely.index**; these files contain in columns for all nodes x y velx and x y vely.

For *data_item_name* you can apply any nodal data record for which the name starts with **node**. For *number_0 number_1* you can specify which parts of the data record should be printed; you can either specify numbers 0, 1, etc. or for **node_dof** you can specify the names of **dof_label** like **-vely**, **-vely** etc., or for **node_dof_calcul** you can specify the names of **post_calcul_label** like **-to_pres**, **-dy_pres** etc.

7.293 **control_print_node_angular** *index switch_x switch_y switch_z*

With this record you can specify that an angle will be included in the files (in stead of coordinates). With *switch_x switch_y switch_z* set to **-yes -yes -no** the angle will measure the number of degrees from the positive global x-coordinate directed to the positive global y-direction. With *switch_x switch_y switch_z* set to **-no -yes -yes** the angle will measure the number of degrees from the positive global y-coordinate directed to the positive global z-direction. With *switch_x switch_y switch_z* set to **-yes -no -yes** the angle will measure the number of degrees from the positive global x-coordinate directed to the positive global z-direction. In 1D you cannot use this **control_print_node_angular** record. In 2D you should not specify *switch_z* and you can only use **-yes -yes**.

The middle point of the axes in which the angle is determined should be specified with **control_print_node_angular_middle**. By example in 2D the angle follows from $\tan(\text{angle}) = \frac{y-y_{\text{middle}}}{x-x_{\text{middle}}}$. In 1D you cannot use this **control_print_node_angular_middle** record. In 2D you should not specify *z_middle* and you should only specify *x_middle y_middle*.

See also **control_print_node**.

7.294 **control_print_node_angular_middle** *index x_middle y_middle z_middle*

See **control_print_node_angular**.

7.295 **control_print_node_geometry** *index geometry_item_name geometry_item_index*

With **control_print_node_geometry** you can restrict the printing to be done only on nodes located on the specified geometry. See also **control_print_node**.

7.296 **control_print_node_sort** *index sort_method*

With **control_print_node_sort** you can set if the printed results should be sorted. In case you use **-angular** for **control_print_node_method**, you can set the *sort_method* to **-angle**. Otherwise you can set the sort method to **-x**, **-y** or **-z** (**-y** is only allowed for 2D or 3D, and **-z** is only allowed for 3D). The results will be sorted starting from small values (of the **-angle**, **-x**, **-y** or **-z**) up to high values.

7.297 `control_print_node_zero` *index switch*

With **control_print_node_zero** you can suppress or activate printing of results with value zero. If you set *switch* to **-yes** then zero valued results will also be printed. If you set *switch* to **-no** then zero valued results will not be printed. Default *switch* is **-yes**. See also **control_print_node**.

7.298 `control_print_tecplot` *index switch*

If *switch* is set to **-yes** a tecplot plot file is printed, and each time results are added to the same file. You can also set *switch* to **-separate_index**; then a new file using the index number will be printed. And also you can set *switch* to **-separate_sequential**; then sequential tecplot files will be printed.

These files contain:

- the primary doffields from **node_dof**
- post calculated results from **node_dof_calcul**

Tecplot uses **zones** to collect data. Zones with nodal results are given names **nodal.....**. Zones with element averaged results are given names **element_averaged.....**. Tecplot uses a strandid integer to select which data is visualised. Tochnog generates in the tecplot file this strandid as follows:

- for nodal results the strandid is the group number and extra 1 is placed at the end
- for element averaged results the strandid is the group number and extra 2 is placed at the end

By example for group 100, the strandid is 1001 for nodal results, and the strandid is 1002 for element averaged results.

Tecplot files are less complete as GID files and GMSH files. Tecplot files can be plotted with the tecplot program, a trademark of Amtec Eng., Inc.

7.299 `control_print_vtk` *index switch*

Activate printing of results in the Visual Toolkit unstructured grid format, which can be plotted by the **paraview** plotting program. See **www.paraview.org**.

For example, if the input file name is **excavation.dat** and *index* is 100 and *switch* is set to **-separate_index** then results are printed in the file is **excavation100.vtk**.

For example, if the input file name is **excavation.dat** and *switch* is set to **-separate_sequential** then results are printed in the files is **excavation0.vtk**, **excavation1.vtk**, etc.

In **paraview** elements are called 'cells' and nodes are called 'points'.

How to get a nice contour plot for the yy-stress:

- **File open** choose file and hit apply button
- **Coloring** choose node_materi_stress and set 4 in stead of magnitude

- **Edit** hit the **Choose preset** button and select something nice.
- **Edit** set **number of table values** to e.g. 80
- **Color Legend** change legend text etc.
- **File Save Screenshot** save picture

How to get a vector plots for velocities:

- **File open** choose file and hit **apply** button
- **Glyph** add glyphs for vectors
- **Glyph type** choose **arrow**
- **Scale mode** choose **vectors**
- **Set scale factor** choose factor to get nice vector lengths
- **Coloring** choose `node_materi_velocity` and choose magnitude

How to find the number of elements depicted in the plot:

- Split the screen at the top right of the layout window, and select spreadsheet view on the second screen
- **View** and then **Selection display inspector**
- In the inspector select **ID** for **Cell labels** and **Point labels**
- Activate the small **select cells on** button in the layout
- With the left mouse button click and drag to select the cells

How to see only elements of a certain groups:

- In **Filters** select **Common** and then select **Threshold**
- In **Scalars** select **element_group**
- In **Minimum** set the minimum group number that you want to see
- In **Maximum** set the maximum group number that you want to see
- In **Coloring** select the data that you want to see

7.300 `control_print_vtk_empty` *index switch*

If *switch* is set to **-yes**, empty elements are included in the vtk file. If *switch* is set to **-no**, empty elements are not included in the vtk file. Default, if **control_print_vtk_empty** is not specified, *switch* is set to **-yes**.

7.301 **control_print_vtk_node_method** *index node_type*

You can set *node_type* to the name of the node record that should be used for the vtk file. Use **-node_start_refined** to get the current values of the **node_start_refined** record. Use **-node** to get the current values of the **node** record. Use **-plus_displacement** to get the current values of the **node** record and added displacement.

If this record is not specified **-node_start_refined** is used.

7.302 **control_relaxation** *index relax_0 relax_1 ...*

Relaxation parameters for adjusting dof's in iterations. This can stabilize the calculation. For example, a relaxation parameter of 0.1 means that the corresponding dof is not completely updated with the iterative change, but only 10 percent of the change is actually applied in a iteration.

If enough iterations are used, the relaxation parameters will not influence the final solution.

You should specify a relaxation parameter term for each principal dof which is present in the calculation (see the start of the data part description for a list of principal dof's; these are velocities, temperature, etc.).

This relaxation done for timestep records with the same index. See also **relaxation**.

7.303 **control_repeat** *index number_of_repeats control_index*

If *number_of_repeats* is larger than 0 the calculation repeats from the *control_index*. The value of *number_of_repeats* is decreased by 1.

A first application is to do many time steps, but print only once in a while:

```
control_timestep 10 1. 100. ...
control_print 20 -node_dof ...
control_repeat 30 80 10
```

In the latter example, first 100 timesteps are taken, then results for **node_dof** are printed; this is repeated 80 times.

Also, this **control_repeat** can typically be used to perform a number of refinements combined with time stepping to a new, refined, solution. This is done a fixed number of times.

In case the repeat jumps back to a **control_timestep** record for which the index equals *control_index*, then that the previous timestep will be used (instead of the timestep specified by the **control_timestep** record).

See also **control_repeat_until_item**.

7.304 **control_repeat_save** *index data_item_name_0 data_item_index_0 data_item_number_0 data_item_name_1 data_item_index_1 data_item_number_1 ...*

This record specifies data that should be saved while repeats are performed with **control_repeat**. The saved results are stored in the records **repeat_save_result** (subsequent repeats write in sub-

sequent indices of `repeat_save_result`).

7.305 `control_repeat_save_calculate` *index switch*

Perform a statistical analysis on data of `repeat_save_result`. The statistical results are placed in `repeat_calculate_result`. The average value and variance will be calculated.

7.306 `control_reset_dof` *index dof_0 dof_1 ...*

The dof's as specified in this record are set to a some new value. For example, *dof_0* is `-eptxx`, etc. As a special option you can use `-all` to reset all dof's.

With `control_reset_value_constant` you can specify the new value to which the dof's should be set. Additionally you can specify values depending on space coordinates with `control_reset_value_linear` etc. The records `control_reset_value_constant`, `control_reset_value_linear` etc. can be arbitrarily combined so that complex dependency of the value of space coordinates is possible. If none of these records is specified then a new value 0 is used.

As a typical example, you can set displacements and strains to zero in a geotechnical calculation, with an `-updated` material description, after the gravity load has been applied. In this way the strains for further deformations can be distinguished more clearly.

The dof's will be reset on all nodes (which are part of the geometry specified in `control_reset_geometry`). In case you use element-wise strains, stresses, etc., see `global_element_dof_apply`, then the dof's will be also be reset on all elements (which are completely part of the geometry specified in `control_reset_geometry`).

As a special option for groundflow calculations, you can set an dofto `-total_pressure` to reset the physical groundflow pore pressure (total pressure) .

Attention: this `control_reset_dof` should not be used to reset displacements if also `support_edge_normal` is present. This is because those `support_edge_normal` supports calculate forces directly from total displacements, and so you would in fact set the support forces also to zero. Normal isoparametric elements use an incremental formulation for stresses however (new stress = old stress + incremental stress from stiffness), so that resetting displacements to zero does not influence the stresses.

Attention: with this `control_reset_dof` option you cannot reset the strains, stresses, forces, etc. in structural elements (springs, interfaces, trusses, ...)

7.307 `control_reset_element_group` *index element_group_number_0 element_group_number_1 ...*

Specifies the specific element groups on which the `control_reset_dof` record with the same index should be applied. If this record is not specified, the `control_reset_dof` record will be done for all element groups (in the specified geometry).

7.308 `control_reset_geometry` *index geometry_item_name geometry_item_index*

Specifies the geometry on which the `control_reset_dof` record with the same index should be applied. If this geometry is not specified, the `control_reset_dof` record will be done for the complete model.

7.309 **control_reset_interface** *index geometry_item_name geometry_item_index*

Reset all interface data like strains, stresses, etc. to 0 for interface elements located in the geometry with name *geometry_item_name* and index *geometry_item_index*.

7.310 **control_reset_interface_strain** *index geometry_item_name geometry_item_index*

Reset all interface strains to 0 for interface elements located in the geometry with name *geometry_item_name* and index *geometry_item_index*. The interface stresses at this moment of resetting will be remembered by Tochnog. In the next time steps the new interface strains start with 0, and change when the interfaces deform further. And in the next time steps the new interface stresses are calculated from the interface stresses at this moment of resetting plus stress due to additional deformation (from the specified stiffness properties).

7.311 **control_reset_value_constant** *index value*

Specifies the value to which dof's of the **control_reset_dof** record are reset. A constant *value* will be used.

7.312 **control_reset_value_exponent** *index a_xb_xc_xd_xe_xa_yb_yc_yd_ye_ya_zb_zc_zd_ze_z*

Specifies the exponential space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $a_x e^{\frac{b_x + c_x x}{d_x + e_x x}} + a_y e^{\frac{b_y + c_y y}{d_y + e_y y}} + a_z e^{\frac{b_z + c_z z}{d_z + e_z z}}$ will be used. In 1D only $a_x b_x c_x d_x e_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y$ should be specified.

7.313 **control_reset_value_linear** *index a_xa_ya_z*

Specifies the linear space distribution to which the dof's of the **control_reset_dof** record are reset. The dependency $a_x x + a_y y + a_z z$ will be used. In 1D only a_x should be specified. In 2D only $a_x a_y$ should be specified.

7.314 **control_reset_value_logarithmic_first** *index a_xb_xc_xd_xe_xa_yb_yc_yd_ye_ya_zb_zc_zd_ze_z*

Specifies the logarithmic space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $a_x \ln(\frac{b_x + c_x x}{d_x + e_x x}) + a_y \ln(\frac{b_y + c_y y}{d_y + e_y y}) + a_z \ln(\frac{b_z + c_z z}{d_z + e_z z})$ will be used. In 1D only $a_x b_x c_x d_x e_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x a_y b_y c_y d_y e_y$ should be specified.

7.315 **control_reset_value_logarithmic_second** *index a_xb_xc_xd_xe_xf_xg_xa_yb_yc_yd_ye_yf_yg_ya_zb_zc_zd_ze_zf_zg_z*

Specifies the logarithmic space distribution to which dof's of the **control_reset_dof** record are reset. The dependency $(a_x + b_x)(e^{c_x \ln(d_x(x+e_x)/f_x)}) + g_x + (a_y + b_y)(e^{c_y \ln(d_y(y+e_y)/f_y)}) + g_y + (a_z + b_z)(e^{c_z \ln(d_z(z+e_z)/f_z)}) + g_z$ will be used. In 1D only $a_x b_x c_x d_x e_x f_x g_x$ should be specified. In 2D only $a_x b_x c_x d_x e_x f_x g_x a_y b_y c_y d_y e_y f_y g_y$ should be specified.

7.316 **control_reset_value_multi_linear** *index* $z_0 value_0 z_1 value_1 \dots$

Specifies the multi-linear space distribution in vertical direction to which the dof's of the **control_reset_dof** record are reset. A multilinear table of value versus z coordinate should be given; at z_0 the value is $value_0$ etc. The z_0, z_1 etc. should have increasing values from low to high; the values should cover all coordinates in the FE mesh for with the reset is done. In 1D not a z coordinate but x coordinate is used instead. In 2D not a z coordinate but y coordinate is used instead.

7.317 **control_reset_value_power** *index* $a_x b_x a_y b_y a_z b_z$

Specifies the power space distribution to which the dof's of the **control_reset_dof** record are reset. The dependency $a_x x^{b_x} + a_y y^{b_y} + a_z z^{b_z}$ will be used. In 1D only $a_x b_x$ should be specified. In 2D only $a_x b_x a_y b_y$ should be specified.

7.318 **control_reset_value_square_root** *index* $a_x b_x c_x a_y b_y c_y a_z b_z c_z$

Specifies the power space distribution to which the to which dof's of the **control_reset_dof** record are reset. The dependency $a_x \sqrt{b_x + c_x x} + a_y \sqrt{b_y + c_y y} + a_z \sqrt{b_z + c_z z}$ will be used. In 1D only $a_x b_x$ should be specified. In 2D only $a_x b_x a_y b_y$ should be specified.

7.319 **control_reset_value_relative** *index* *switch*

If *switch* is set to **-yes** the values as specified by **control_reset_value** etc. are used as relative factor by which the dof's are changed. So for example if 0.1 is given in **control_reset_value_constant**, then the dof's will be multiplied with 0.1.

Default, if **control_reset_value_relative** is not specified, then *switch* is set to **-no** so the values will be used absolute and not relative.

7.320 **control_restart** *index* *switch*

If *switch* is set to **-yes** then the calculation continues with the undeformed mesh. The dof's (in the **node_dof** records) are reset to the initial values. And **time_current** is set to the initial time.

This allows you to calculate some path dependent behavior completely from the start with a refined mesh.

7.321 **control_safety_slip** *index* *switch*

If *switch* is set to **-yes** a slip safety factor calculation will be performed with the method as described in [4]. The calculated safety factor F_s is:

$$F_s = \frac{\int \tau_{mc} dA}{\int \tau dA}$$

where τ_{mc} is the maximum possible shear stress according to the mohr-coulomb condition using the actual normal stress, τ is the actual shear stress and dA is the surface area in the integral. The advantage of this safety factor definition is that it can be evaluated at any stress state, by example

the gravity stress state, without any further timesteps with friction angle and cohesion reduction. The definition simply compares the actual current shear stress relative to the maximum possible shear stress following from mohr-coulomb and the current normal stresses.

The user needs to specify over which surface the integration of the safety factor needs to be performed. See **safety_slip_circle_grid_***, etc.

A critical slip surface will be calculated for each set of **safety_slip_circle_grid_***, etc. (thus for each separate index of these a critical surface will be calculated). You can specify also **safety_slip_set** however, which defines the indices of **safety_slip_circle_grid_***, etc. belonging to a specific set. The overall minimal safety factor will be determined for all safety geometries belonging to the set.

This **control_safety_slip** is available for **group_materi_plasti_mohr_coul**, **group_materi_plasti_mohr_coul_direct**, **group_materi_plasti_druck_prag** and **group_materi_plasti_hypo_wolffersdorff**.

As a special option you can set the *switch* not to **-yes** but to a number 1, 2, 3, .. instead. Then this number 1, 2, 3, ... is used by tochnog as the number of automatic safety calculations of the critical slip surface. By example if you use slip circles (specified by middle points and radii) after the first safety calculations a specific middle point and radius will have the lowest safety factor. Then in the next safety calculation tochnog will reduce the area of middle points and the set of radii to a smaller zone around that critical middle point and radius. With this smaller zone a new safety analysis will lead to a new critical middle point and radius somewhere in the reduced zone. Then again a smaller zone will be used, leading to again a new critical middle point and radius, etc. etc. This repetition of reducing the zone of middle points and radii will be done such many times as set in the number, so 1, 2, 3, ... Typically the number 2 could be used.

Slip surfaces will be drawn in GID plots (see **control_print_gid** for GID plotting). For each slip surfaces the safety factor can be plot. Moreover, also a local safety factor can be plot, which is the local ratio of shear stress and maximum possible shear stress.

Slip surfaces crossing a boundary with prescribed displacements (or velocities) non valid since the slip velocities are in general not compatible with the prescribed velocities on such boundary.

7.322 control_slide_damping_apply *index switch*

If *switch* is set to **-yes** then any **slide_damping** records will be applied. If *switch* is set to **-no** then any **slide_damping** records will be not applied. Default if **control_slide_damping_apply** is not specified then *switch* is **-yes**.

7.323 control_slide_stiffness_apply *index switch*

If *switch* is set to **-yes** then any **slide_stiffness** records will be applied. If *switch* is set to **-no** then any **slide_stiffness** records will be not applied. Default if **control_slide_stiffness_apply** is not specified then *switch* is **-yes**.

7.324 control_solver *index solver_type*

If *solver_type* is set to **-diagonal** then only the main diagonal of the system matrix will be used for the solution of all dof's. This gives the program an explicit like structure. In fact, if **control_timestep_iterations** is set to 1, then a classical explicit finite element program is obtained.

If *solver_type* is set to **-matrix_iterative_bicg** then the complete system matrix will be used for solution of the principal dof's (see the initialization section for an explanation on principal dof's). A diagonal Preconditioned Biconjugate Gradient method is applied.

If *solver_type* is set to **-matrix_pardiso** then the pardiso solver will be used for solution of the principal dof's.

If *solver_type* is set to **-matrix_superlu** then the pardiso solver will be used for solution of the principal dof's. The superlu solver is only available for linux 64bit.

If *solver_type* is set to **-none** then only the matrices and right-hand sides are setup, but the equations are not really solved.

7.325 **control_solver_bicg_error** *index error*

With *error* you set the termination error ratio between the initial and final error in the bicg iterations. Default *error* is set to **1.e-13**.

See also **solver_bicg_error**. This **control_solver_bicg_error** record overrules **solver_bicg_error** if both are specified.

7.326 **control_solver_bicg_restart** *index nrestart*

With *nrestart* you set the number of restarts in the bicg iterations. Default *nrestart* is set to 0.

See also **solver_bicg_restart**. This **control_solver_bicg_restart** record overrules **solver_bicg_restart** if both are specified.

7.327 **control_solver_bicg_stop** *index switch*

If *switch* is set to **-yes**, the calculation is stopped if the bicg solver does not converge. If *switch* is set to **-no**, the calculation is not stopped if the bicg solver does not converge. Default *switch* is set to **-yes**.

See also **solver_bicg_stop**. This **control_solver_bicg_stop** record overrules **solver_bicg_stop** if both are specified.

7.328 **control_solver_matrix_save** *index switch*

If *switch* is set to **-yes**, the solver saves and applies the decomposed matrix, but not in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep. This can save CPU time, since further decompositions of the matrix are not required anymore (only backsubstitution to find the solution vector).

If *switch* is set to **-no**, the solver does not save the decomposed matrix.

If *switch* is set to **-always**, the solver saves and applies the decomposed matrix, even in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep.

This option is only available in combination with the pardiso solver.

Side remark: Tochnog mostly uses a linear matrix in iterations (no plasticity effect in the matrix).

Only in special cases like hypoplasticity, user supplied routines, etc. the current stiffness matrix is used.

7.329 **control_solver_pardiso_out_of_core** *index switch*

If *switch* is set to **-yes** the pardiso solver is called with a 'out of core' option. See for further the pardiso solver in the the intel mkl library. Default *switch* is **-no**.

7.330 **control_solver_pardiso_ordering** *index ordering*

Set the number *ordering* to one of the following:

- 0 The minimum degree algorithm.
- 2 The nested dissection algorithm from the METIS package.
- 3 The parallel (OpenMP) version of the nested dissection algorithm.

Default *ordering* is **3**. For more information see pardiso info at intel.

7.331 **control_support_edge_normal_damping_apply** *index switch*

If *switch* is set to **-yes** then all **support_edge_normal_damping** records will be applied. If *switch* is set to **-no** then all **support_edge_normal_damping** records will not be applied. Default, if **control_support_edge_normal_damping_apply** is not specified, then *switch* is set to **-yes**.

7.332 **control_support_edge_normal_stiffness_freeze** *index switch*

If *switch* is set to **-yes**, tochnog freezes the stiffness forces generated by **support_edge_normal**. The stiffness forces remain at their present value and will not change anymore. A typical application is earthquake or vibration analysis where you first impose gravity including stiffness at supports, then freeze the forces at the supports, and then in the earthquake or vibration analysis use only damping at the supports to model absorbing boundaries which absorb further force changes at the boundaries.

```
( support properties )
support_edge_normal 10 ...
support_edge_normal_damping 10 ...
...
( calculate gravity stresses )
control_timestep 10 ...
control_support_edge_normal_damping_apply 10 -no
...
( freeze stiffness forces at boundary )
control_support_edge_normal_stiffness_freeze 20 -yes
...
( calculate earthquake or vibrations )
control_timestep 30 ...
control_support_edge_normal_damping_apply 30 -yes
```

control_inertia_apply 30 -yes

7.333 **control_system_call** *index integer_value*

Specifying this record tochnog calls a system command. You need to program that command yourself. On linux provide a **tochnog_system_call.sh** file which is executable. On MS Windows provide a **tochnog_system_call.bat** file.

In the command you can place commands that you want to be executed. By example, if you put in the linux file the command **date >> system_call.out** you get the output of the **date** command appended to **system_call.out**. Another example is sending you an automatic email indicating that the calculation reached a certain point or is almost finished.

The command is called with *integer_value* as first argument. You can use this integer value in your command (eg by using \$1 in the linux shell script command).

7.334 **control_timestep** *index step_size time_increment step_size time_increment* ...

These records define sets of time steps of size *step_size* which are to be taken till the time is increased by *time_increment*. In the example below time steps of 0.1 are taken from time 0.0 up to time 1.0. Then time steps of 0.2 are taken up to time 2.0

control_timestep 0 0.1 1. 0.2 1.

7.335 **control_timestep_adjust_minimum_iterations** *index switch*

If *switch* is set to **-yes** Tochnog will increase the minimum number of iterations in a timestep if it thinks that is helpful for the specific input file that you are running; this is done in combination with **control_timestep_iterations_automatic** or **control_timestep_reduce_automatic**. If *switch* is set to **-no** Tochnog will not do so, and keep 2 as the minimum number of iterations. Default, if **control_timestep_adjust_minimum_iterations** is not specified, *switch* is set to **-yes**.

7.336 **control_timestep_iterations** *index number_of_iterations*

This sets a fixed number of equilibrium iterations in each time step (for time steps of the **control_timestep** record with the same index). For many iterations, the time stepping is Euler implicit. For few iterations the time stepping becomes explicit. Default *number_of_iterations* is 2.

In dynamic analysis, with the default number of 2 iterations you gain numerical stability, at the expense of numerical damping however. To prevent this numerical damping use 1 iteration instead.

As an alternative, you can use **control_timestep_iterations_automatic** or **control_timestep_reduce_automatic**

7.337 **control_timestep_iterations_automatic** *index ratio_criterium minimal_timestep maximum_timestep*

After specification of this record, iterations will be performed until *ratio* in **post_node_rhside_ratio** is less than *ratio_criterium*. Typically, set *ratio_criterium* to 0.01 or 0.001.

The time step size is increased if the number of iterations is substantially lower then the wished (preferred) number of iterations. The time step size is decreased if the number of iterations is substantially larger then the wished (preferred) number of iterations.

The time step specified in **control_timestep** is used as initial step. The time step is not allowed to become higher then *maximum_timestep*. The time step is not allowed to become lower then *maximum_timestep*.

The initial step as specified in **control_timestep**, should be sufficient small so that this automatic algorithm can fulfill the *ratio_criterium* in that initial step.

After the iterations in a step are finished, Tochnog performs one extra iterations to update strains, stresses, etc with the last velocity fields. In this extra iteration also the **post_node_rhside_ratio** will be recalculated, and thus may become different from the previous value that was used to determine if the iterations should be stopped.

See also **control_timestep_iterations_automatic_stop**, and **control_timestep_iterations_automatic_min**

7.338 **control_timestep_iterations_automatic_minimum_maximum_wished** *index minimum_iterations maximum_iterations wished_iterations*

This sets the minimum number of allowed iterations, the maximum number of allowed iterations, and the wished (preferred) number of iterations for the automatic time stepping mechanism as specified by **control_timestep_iterations_automatic** with the same index. The default for this record is 2 8 4. The maximum number of allowed iteration should be 2 or larger.

7.339 **control_timestep_iterations_automatic_stop** *index switch*

If you set *switch* in **control_timestep_iterations_automatic_stop** to **-yes** then the calculation does stop if the minimal timestep size is reached. If you set *switch* in **control_timestep_iterations_automatic_stop** to **-no** then the calculation does not stop if the minimal timestep size is reached, and the present timestepping will be finished.. If you set *switch* in **control_timestep_iterations_automatic_stop** to **-continue** then the calculation does not stop if the minimal timestep size is reached, and the present timestepping will not be finished.. Default, if **control_timestep_iterations_automatic_stop** is not specified, then *switch* is set to **-yes**.

7.340 **control_timestep_iterations_extra** *index switch*

If *switch* is set to **-yes** an extra iteration is performed at the end of each timestep. The extra iteration takes care that strains and stresses become consistent with the calculated velocity and displacement field. If *switch* is set to **-no** the extra iteration is not done.

This option is usefull in dynamic structural calculations where you want to eliminate artificial dynamical damping. Such artificial damping is caused by relatively large timesteps, which may be needed to get realistic computer times. When you set **control_timestep_iterations_extra** to **-no** and **control_timestep_iterations** to 1 the numerical scheme is such that there is no artificial

numerical damping in the dynamic analysis, even for large timesteps.

If you use this **control_timestep_iterations_extra** option, the **post_node_rhside_ratio** becomes invalid; it is not determined correctly in combination with this **control_timestep_iterations_extra** since the stresses are not calculated at the end of each timestep.

Default *switch* is set to **-yes**.

7.341 **control_timestep_multiplier** *index multiplier*

If this record is specified, each new time step size is *multiplier* * old time step size. The *step_size* as specified in **control_timestep** will only be used as the initial time step.

This option is handy to study physical processes which develop more slowly when time proceeds. A typical example is consolidation analysis in geotechnics.

7.342 **control_timestep_reduce_automatic** *index n_subdivisions n_subdivisions_levels maximum_iterations*

If the error ratio in a timestep exceeds the maximum error ratio after *maximum_iterations* the timestep size will be subdivided into *n_subdivisions*. The maximum error ratio is specified in **control_timestep_reduce_automatic_ratio_criterium**. This maximum number of subdivisions levels, including the initial undivided level, is *n_subdivisions_levels*. The initial step size and time increment should be set in **control_timestep**.

The maximum number of allowed iteration should be 2 or larger.

With this algorithm you can ensure that time-points will always arrive exactly at times of interest at which actions are taken in time tables or so; the **control_timestep_iterations_automatic** might leap over such times of interest.

After the iterations in a step are finished, Tochnog performs one extra iterations to update strains, stresses, etc with the last velocity fields. In this extra iteration also the **post_node_rhside_ratio** will be recalculated, and thus may become different from the previous value that was used to determine if the iterations should be stopped.

A typical example:

```
control_timestep_reduce_automatic 0 4 4 8
```

7.343 **control_timestep_reduce_automatic_ratio_criterium** *index ratio_criterium*

See **control_timestep_reduce_automatic**. Default, if **control_timestep_reduce_automatic_ratio_criterium** is not specified, *ratio_criterium* is set to 0.001.

7.344 **control_timestep_reduce_automatic_stop** *index switch*

See **control_timestep_reduce_automatic**.

If you set *switch* in **control_timestep_reduce_automatic_stop** to **-yes** then the calculation does stop if the error ratio is exceeded on the maximum amount of subdivisions levels. If you

set *switch* in **control_timestep_reduce_automatic_stop** to **-no** then the calculation does not stop if the error ratio is exceeded on the maximum amount of subdivisions levels, and the present timestepping will be finished. If you set *switch* in **control_timestep_reduce_automatic_stop** to **-continue** then the calculation does not stop if the error ratio is exceeded on the maximum amount of subdivisions levels, and the present timestepping will not be finished. Default, if **control_timestep_reduce_automatic_stop** is not specified, then *switch* is set to **-yes**.

7.345 **control_timestep_reduce_displacement** *index maximum_component*

This option allows you to control the maximum allowed displacement per step in a calculation. In fact, the maximum displacement component in either x-direction, y-direction or z-direction anywhere in the structure is checked. If it exceeds the *maximum_component*, then the timestep size is lowered.

This option cannot be used i.c.w. other **control_timestep_iterations_automatic*** and **control_timestep_reduce_automatic*** options.

7.346 **control_timestep_until_data** *index data_item_name_0 data_item_index_0 data_item_number_0 data_item_name_1 data_item_index_1 data_item_number_1 ...*

With this record you can specify conditions for which the timesteps with the same index should be stopped. For each specified data item name, index and number you can specify a minimum value in **control_timestep_until_minimum** and a maximum value in **control_timestep_until_maximum**. A typical example:

```
control_timestep 10 ...
control_timestep_until_data 10 post_point_dof 3 -velx
control_timestep_until_minimum 10 -120.
control_timestep_until_maximum 10 +120.
```

7.347 **control_timestep_until_maximum** *index maximum_0 maximum_1 ...*

7.348 **control_timestep_until_minimum** *index minimum_0 minimum_1 ...*

7.349 **control_truss_rope_apply** *index switch*

If *switch* is set to **-no**, any truss rope data in the input file will be ignored. This is done for timestep records with the same index.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with truss rope data. See also **truss_rope_apply**.

7.350 **control_zip** *index switch*

If *switch* is set to **-yes** all ***flavia***, ***msh**, **vtk**, ***.plt** and ***dbs** files are zipped with the **gzip** program. The **gzip** program should be installed on your computer.

This comes convenient in large calculation with lots of output, where you want to use results later and save disk space during the calculation.

7.351 **crack_element_group** *element_group*

Calculate stress intensity factor. The elements with the specified *index element_group* are around the crack, so the cracking material; you need to use **tria6** elements. The nodes *node_0 node_1 ...* are the specific nodes at the tip of the crack. The crack intensity factor is calculated with **control_crack index -calculate_stress_intensity_factor**. The result is written in **crack_stress_intensity_factor**.

See also the files **tochnog/test/other/crack*.dat**.

7.352 **crack_node** *node_0 node_1 ...*

See **crack_element_group**.

7.353 **convection_apply** *switch*

If *switch* is set to **-yes**, the convection of a material with respect to the mesh is allowed. If *switch* is set to **-no**, the convection of a material with respect to the mesh is not allowed. This is done for all timesteps. The convection of material with respect to the mesh is not allowed in combination with **group_materi_plasti....** and **group_materi_umat** records (*switch* will be set to **-no**). Default *switch* is set to **-no**.

See also **control_convection_apply**.

7.354 **convection_stabilization** *switch*

Because of finite discretisation sometimes unrealistic results may be obtained (wiggles, etc.). If *switch* is set to **-yes** results are stabilized with a minimal amount of artificial diffusion. If *switch* is set to **-maximal** results are stabilized with a maximal amount of artificial diffusion. If *switch* is set to **-no** results are not stabilized.

7.355 **data_activate** *index data_item_name_0 data_item_name_1 ... switch*

With this record you can set data items to become activated if *switch* is set to **-yes** or de-activated if *switch* is set to **-no**. The *data_item_name* specifies a data record name.

7.356 **data_activate_time** *index time*

Time point at which the record **data_activate** with the same index is evaluated. If this record is not specified, the **data_activate** is evaluated at the start of the calculation.

7.357 **data_delete** *index data_item_name index_range*

Similar to **control_data_delete**, but now not as control record however.

7.358 **data_delete_time** *index time*

Time point at which the record **data_delete** with the same index is evaluated. If this record is not specified, the **data_delete** is evaluated at the start of the calculation.

7.359 **dependency_apply** *switch*

If *switch* is set to **-yes**, dependencies like specified in **dependency_diagram** and **dependency_item** are included in the calculation. If *switch* is set to **-no**, these dependencies are not included. This is done for all timestep records.

Default *switch* is set to **-yes**. See also **control_dependency_apply**.

7.360 **dependency_diagram** *index dof_value_0 ... data_item_value_0 ...*

See **dependency_item**.

7.361 **dependency_method** *index method*

See **dependency_item**.

7.362 **dependency_geometry** *index geometry_item_name geometry_item_index*

See **dependency_item**.

7.363 **dependency_item** *index data_item element_group dofn*

This record allows you to make an element data item **group_*** dependent on one of the dof's, see **dof_label** for dofnames, or on one of the post calculation results, see **post_calcul_label** for post calculation names. This is done for n values of the dof (n should be at least 2). The dependency should be specified in the **dependency_diagram** record (same index) with a multi linear diagram. In the diagram first a set of dof's values should be specified. Second the set of data item values for those dof values should be specified. Some examples are given below.

Temperature dependent Young's modulus of element_group 1 ($E = 1.e10$ at temperature 1, etc.):

```
dependency_item 1 -group_materi_elasti_young 1 -temp 4
dependency_diagram 1 1. 2. 3. 4. 1.e10 1.e9 1.e8 3.e5
```

Temperature dependent Young's moduli in two maxwell chains of element_group 1 (for the first chain the moduli 1.e10, 1.e9, ... for the second chain the moduli 1.e12, 1.e11, ... all relaxation times are $1. 10^{-2}$.):

```
dependency_item 1 -group_materi_maxwell_chain 1 -temp 4
dependency_diagram 1
1. 2. 3. 4.
```

```

1.e10 1.e9 1.e8 3.e5
1.e-2 1.e-2 1.e-2 1.e-2
1.e12 1.e11 1.e10 3.e7
1.e-2 1.e-2 1.e-2 1.e-2

```

As a special option, *dof* can be set to **-time_current**. This allows for time-dependent properties (aging). The example below shows time dependent Young's modulus of element_group 1 ($E = 1.e10$ at time 0, etc.):

```

dependency_item 1 -group_materi_elasti_young 1 -time_current 4
dependency_diagram 1 0. 1. 2. 3. 1.e10 1.e9 1.e8 3.e5

```

As a special option, *element_group* can be set to **-all**, so that the dependency diagram will be used for all groups.

As another special option, *dof* can be set to **-x**, **-y** or **-z**. This allows for dependency on one of the space coordinates. The example below shows a von-mises stress dependent on the z-coordinate for element_group 1:

```

dependency_item 1 -group_materi_plasti_vonmises 1 -z 4
dependency_diagram 1 -300. -200. -100. 0. 1.e5 1.e4 1.e3 1.e2

```

In 1D only **-x** can be used, in 2D only **-x** and **-y** can be used, and in 3D all of **-x**, **-y** and **-z** can be used.

The dependencies are available only for real precision data (and thus not for integer data). The **dependency_diagram** values should be specified from low to high values for the dof.

The **dependency_method** can be set to either **-use** or **-multiply**; with **-use** you specify that the values of **dependency_diagram** will overwrite specified values for the data item; with **-multiply** you specify that the values of **dependency_diagram** will multiply specified values for the data item; default, if **dependency_method** is not specified, **-use** will be used.

With the **dependency_type** record you can require that the cosinus, sinus or tangent of a data value is used in the dependency (in stead of the data value directly itself). The *type* can be set to either **-cosinus**, **-sinus** or **-tangent**. This is typically convenient for geotechnical safety factor calculations where you want that for a mohr coulomb law the cohesion and tangent of the friction angle are decreased at the same ratio in time. If you don't specify **dependency_type** the value itself will be changed. To be clear we give the following four examples. If **dependency_method** is set to **-use** and **dependency_type** is not specified, then the value specified in the dependency diagram will be used for the data. If **dependency_method** is set to **-use** and **dependency_type** is set to **-tangent**, then the arc-tangent of the value specified in the dependency diagram will be used for the data. If **dependency_method** is set to **-multiply** and **dependency_type** is not specified, then the value specified in the dependency diagram will be multiplied with the original value for the data, and the result will be used as new value for for the data. If **dependency_method** is set to **-multiply** and **dependency_type** is set to **-tangent**, then the value specified in the dependency diagram will be multiplied with the tangent of the original value for the data, the arc-tangent of the result will be taken, and the final result will be used as new value for for the data.

With the **dependency_number** record you can require that you only want to make one specific number of the data (0 for the first value, 1 for the second value, etc.) dependent; in this case,

you should specify only that specific value in **dependency_diagram**. If you don't specify **dependency_number**, then all values of the record are made dependent, and thus all values should be specified in **dependency_diagram**. The **dependency_number** can only be used for data records which have a fixed number of values (eg mohr coulomb plasticity data always has the fixed number of three values, the friction angle, cohesion, and flow angle).

The **dependency_geometry** can be set to select a geometry for which the dependency is valid; outside the geometry the dependency will not be used; default, if **dependency_geometry** is not specified, no geometry selection will be used.

The following gives as example lowering the tangent of the mohr coulomb friction angle with a factor in time, for the elements of all groups within a radius distance from a point:

```

geometry_point 10 ...
...
dependency_item 1 -group_materi_plasti_mohr_coul -all -time_current 2
dependency_number 1 0 (only for the friction angle)
dependency_method 1 -multiply (use specified diagram as multiplication factor)
dependency_type 1 -tangent (for the tangent, so not for the value itself)
dependency_diagram 1 10. 11. 1. 0. (lower the tangent of friction angle between
time 10 to time 11 from original value to 0)
dependency_geometry 1 -geometry_point 10 (do that only within a certain radius
of a point)

```

You can use **print_group_data** to get the result for the calculated values using the dependency diagram. In fact, most **group_*** records can be used in the dependency diagram, but not all. Thus checking if things go like you want with the **print_group_data** is stringly adviced.

7.364 **dependency_number** *index number*

See **dependency_item**.

7.365 **dependency_type** *index type*

See **dependency_item**.

7.366 **dof_element_dof** *dof_per_element_0 dof_per_element_1 ...*

This record is for printing only. It is not meant as user input record. After the calculation the *dof_per_element_0* , *dof_per_element_1* etc. contain a **-yes** or **-no**. In case a dof is default calculated per element, so the field is non-continuous, a **-yes** is set. In case a dof is default calculated as continuous field a **-no** is set. This default calculation can be overruled by **global_element_dof_apply**.

7.367 **dof_label** *dof_0 dof_1 ...*

This record will be filled with labels of the dof's in the correct order. This information is required for understanding records like **node_dof** etc. The sequential order for the primary dof's will match the order in which they are specified in the initialization part.

The total list of possible doflabels is:

-accx acceleration in x -direction, **-accy**, **-accz**,

-cchis0, **-cchis1** cam clay history variables,

-dam damage,

-dens density,

-dipriscohisv, **-dipriscohis1**, ..., **di prisco** plasticity history variables,

-disx displacement in x -direction, **-disy**, **-disz**,

-rdisx relative displacement in x -direction, **-rdisy**, **-rdisz**,

-ener material strain energy,

-epexx xx -strain elastic, **-epexy**, **-epexz**, **-epeyy**, **-epeyz**, **-epezz**,

-eppxx xx -strain plastic, **-eppxy**, **-eppxz**, **-eppyy**, **-eppyz**, **-eppzz**,

-eppcaxx xx -strain plastic cap model, **-eppcaxy**, **-eppcaxz**, **-eppcayy**, **-eppcayz**, **-eppcazz**,

-eppcoxx xx -strain plastic compression model, **-eppcoxy**, **-eppcoxz**, **-eppcoyy**, **-eppcoyz**, **-eppcozz**,

-eppdixx xx -strain plastic diprisco model, **-eppdixy**, **-eppdixz**, **-eppdiyy**, **-eppdiyz**, **-eppdizz**,

-eppdrxx xx -strain plastic druckprag model, **-eppdrxy**, **-eppdrxz**, **-eppdryy**, **-eppdryz**, **-eppdrzz**,

-eppgencamxx xx -strain plastic generalised non associate cam clay for bonded soils model, **-eppgencamxy**, **-eppgencamxz**, **-eppgencamy**, **-eppgencamyz**, **-eppgencamzz**,

-epphaxx xx -strain plastic hardsoil model, **-epphaxy**, **-epphaxz**, **-epphayy**, **-epphayz**, **-epphazz**,

-eppmaxx xx -strain plastic matsuokanakai model, **-eppmaxy**, **-eppmaxz**, **-eppmayy**, **-eppmayz**, **-eppmazz**,

-eppmoxx xx -strain plastic mohr-coulomb model, **-eppmoxy**, **-eppmoxz**, **-eppmoyy**, **-eppmoyz**, **-eppmozz**,

-epptexx xx -strain plastic tension model, **-epptexy**, **-epptexz**, **-eppteyy**, **-eppteyz**, **-epptezz**,

-eppvoxx xx -strain plastic von-mises model, **-eppvoxy**, **-eppvoxz**, **-eppvoyy**, **-eppvoyz**, **-eppvozz**,

-eppmolxx xx -strain mohr-coulomb model for all laminates , **-eppmolxy**, **-eppmolxz**, **-eppmolyy**, **-eppmolyz**, **-eppmolzz**,

-eppmolxxx xx -strain mohr-coulomb model laminate $k=0,...,5$, **-eppmolkxy**, **-eppmolksz**, **-eppmolkyz**, **-eppmolkyz**, **-eppmolkzz**,

-epptekxx xx -strain tension model for all laminates , **-epptelxy**, **-epptelxz**, **-epptelyy**, **-epptelyz**, **-epptelzz**,

-epptelkxx xx -strain tension model laminate $k=0,...,5$, **-epptelkxy**, **-epptelkxz**, **-epptelkyy**,
-epptelkyz, **-epptelkzz**,
-eptxx xx -strain total, **-eptxy**, **-eptxz**, **-eptyy**, **-eptyz**, **-eptzz**,
-f plasticity yield rule,
-fn nonlocal plasticity yield rule,
-fscal time derivative of scalar,
-gvelx ground water velocity in x -direction, **-gvely**, **-gvelz**.
-hisv0, **-hisv1**, ..., material history variables,
-kap plastic hardening parameter kappa,
-kapsh shear plastic hardening parameter kappa,
-phimob mobilized friction angle plasticity,
-pres hydraulic pressure head,
-pres_gradx gradient hydraulic pressure head in x direction, **-pres_grady**, **-pres_gradz**
-rhoxx xx plastic kinematic hardening, **-rhoxy**, **-rhoxz**, **-rhoxyy**, **-rhoxyz**, **-rhozz**,
-rotx rotation around x -direction, **-roty**, **-rotz**,
-scal scalar,
-sigxx xx -stress, **-sigxy**, **-sigxz**, **-sigyy**, **-sigyz**, **-sigzz**,
-sigmkxx xx -stress in the k -th maxwell chain, **-sigmkxy**, **-sigmkxz**, **-sigmkyy**, **-sigmkyz**, **-sigmkzz**,
-strtokap total strain hardening parameter,
-strtocokap compression part of total strain hardening parameter,
-strtoshkap shear part of total strain hardening parameter,
-strtotekap tension part of total strain hardening parameter,
-temp temperature,
-trboslx bond slip displacement in x -direction, **-trbosly**, **-trboslz**,
-velx velocity in x -direction, **-vely**, **-velz**,
-velix integrated velocity in x -direction, **-veliy**, **-veliz**,
-void material void fraction.
-work material second order work.

Furthermore, **-xvelx** denotes the spatial x -derivative of **-velx** in x -direction, etc.. Finally, **-tvelx**

denotes the first time derivative of **-velx**, etc.. The time derivative and the space derivatives are only calculated if **derivatives** is included in the initialization part.

For example, the following might be seen after a print of the database

```
echo -yes
number_of_space_dimensions 2
derivatives
condif_temperature
end_initia
...
dof_label -temp -xtemp -ytemp -ttemp
...
```

Or, for example, the following might be seen after a print of the database

```
echo -yes
number_of_space_dimensions 2
condif_temperature
end_initia
...
dof_label -temp
...
```

7.368 **dof_limit** *lower_dof_0 upper_dof_0 lower_dof_1 upper_dof_1 ...*

With this record you can specify the lower and upper allowed values for all primary dof's. With *lower_dof_0* you specify the lower allowed value for the first dof. With *upper_dof_0* you specify the upper allowed value for the first dof. Etc.

7.369 **dof_principal** *number_0 number_1 ...*

This record is for printing only. It is not meant as user input record. After the calculation it contains for all principal dofs (velocities, temperatures, etc.) the corresponding principal number (0 for the first principal dof, 1 for the second principal dof, etc.). In case a dof is not principal (strains, stresses, etc.) the number is set to **-no**. You can see in the **dof_label** record after the calculation the dof names corresponding to **dof_principal**.

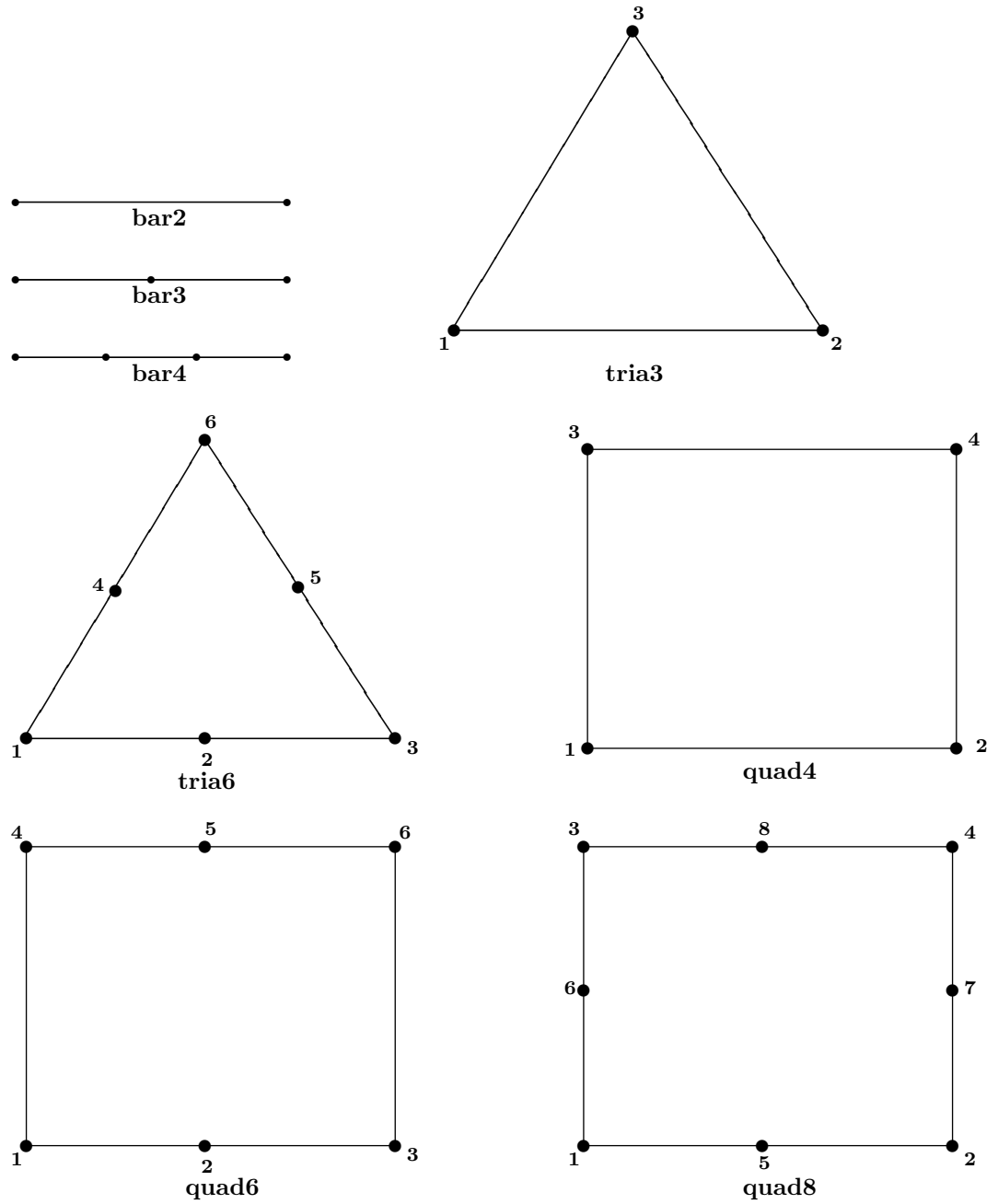
7.370 **element** *index element_name node_0 node_1 node_2 ...*

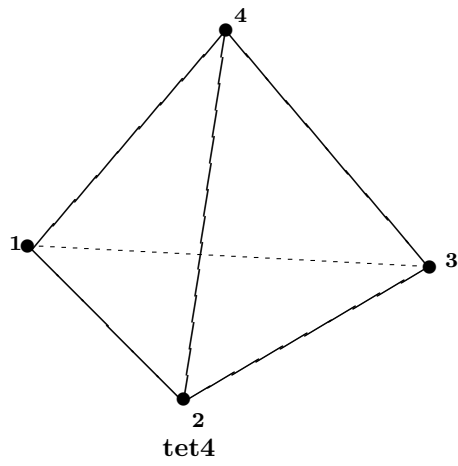
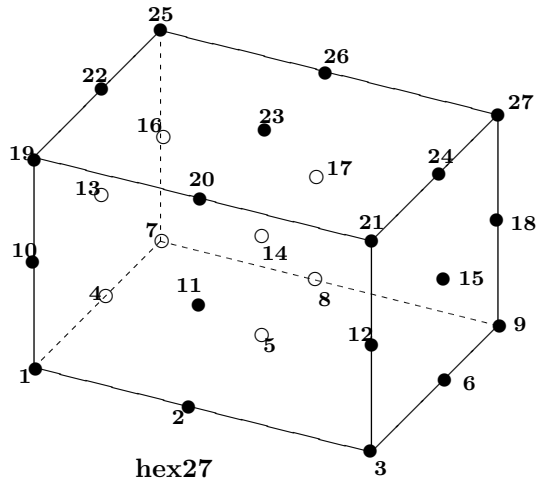
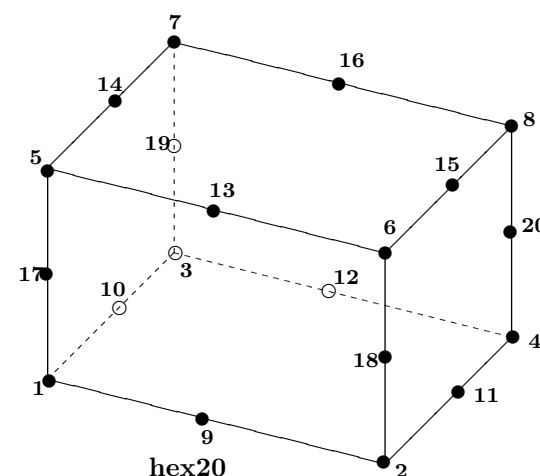
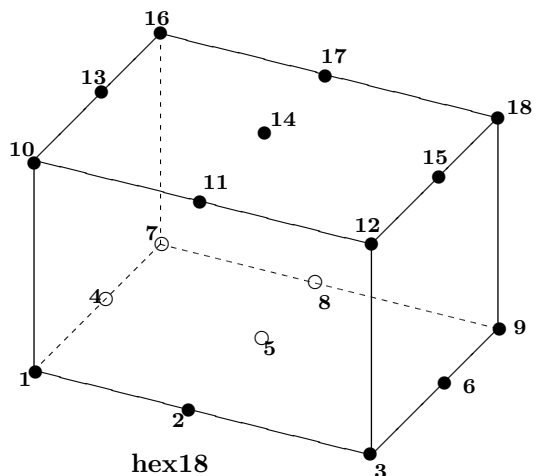
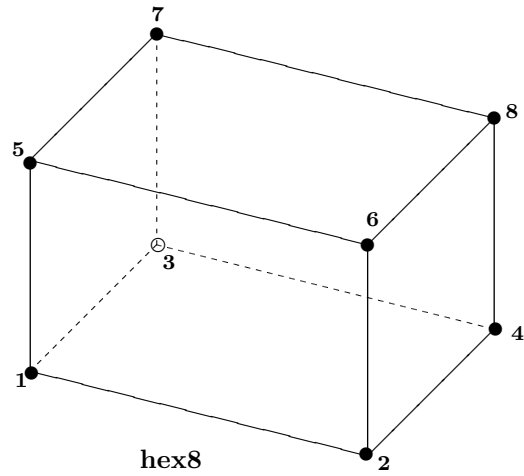
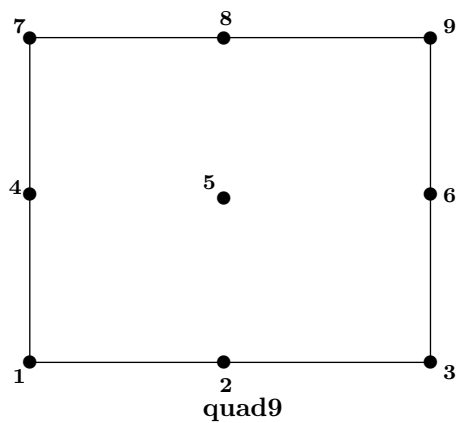
Nodal connective of element *index*. In 1D, *element_name* is **-bar2** (2 noded bar), **-bar3**, **-bar4**. In 2D, *element_name* is **-tria3** (3 noded triangle), **-tria6** (6 noded triangle), **-quad4** (4 noded quadrilateral), **-quad6** (6 noded quadrilateral, 2 sides of 3 nodes), **-quad8**, **-quad9**, **-quad16**. In 3D, *element_name* is **-tet4** (4 noded tetrahedral), **-prism6** (6 noded prismatic), **-prism12** (12 noded prismatic), **-prism15** (15 noded prismatic), **-prism18** (18 noded prismatic), **-tet10** (10 noded tetrahedral), **-hex8** (8 noded hexahedral), **-hex18** (18 noded hexahedral, 2 sides of 9

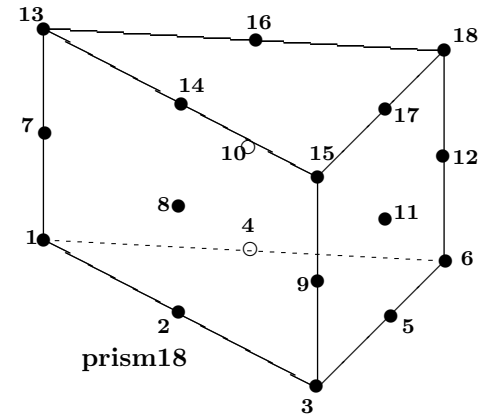
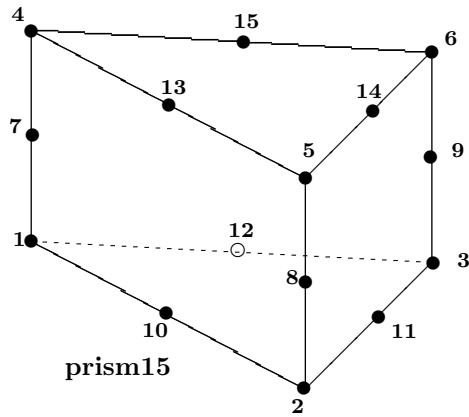
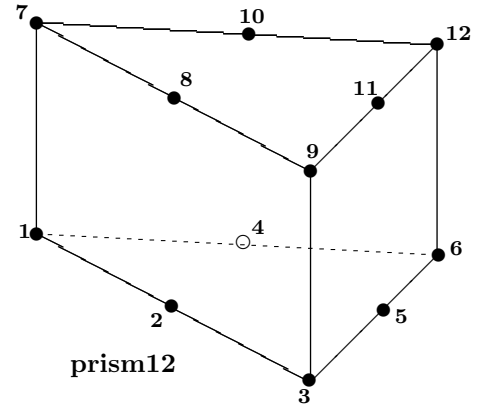
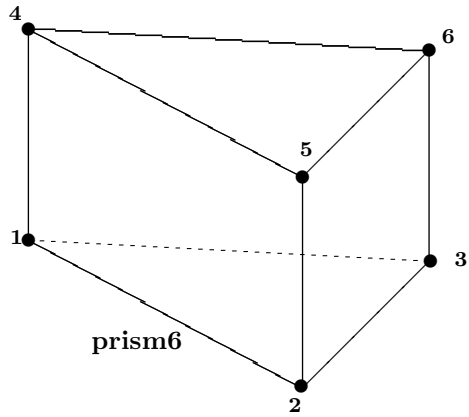
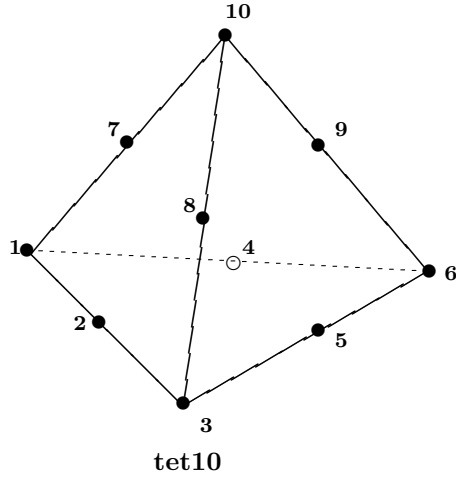
nodes), **-hex20** (20 noded hexahedral, not formally available yet, still being tested, use with care), **-hex27**.

Further possibilities for *element_name* are: **-spring2** (2 noded spring), **-contact_spring1** (1 noded contact element), **-contact_spring2** (2 noded contact element), the two nodes may have the same position in space. **-truss** (truss element), **-beam** (beam element), **-truss_beam** (combined truss-beam element).

Some of the elements are drawn below.







See also: **group_type** and **group_integration_points**.

7.371 element_beam_direction *index dir_x,x dir_x,y dir_x,z dir_y,x dir_y,y dir_y,z dir_z,x dir_z,y dir_z,z*

After the calculation, this record will be filled with the direction of a beam in space. The first three values give the direction of the local beam x direction, that is the beam torsion axis. The second three values give the direction of the local beam y direction, that is the beam y bending axis. The third three values give the direction of the local beam z direction, that is the beam z bending axis.

The *index* specifies the beam element number.

7.372 **element_beam_direction_z** *index dir_z,x dir_z,y dir_z,z*

The *index* specifies the beam element number.

Same as **group_beam_direction_z**, but now per element however.

7.373 **element_beam_force_moment** *index force_x_first_node force_y_first_node force_z_first_node moment_x_first_node moment_y_first_node moment_z_first_node force_x_second_node force_y_second_node force_z_second_node moment_x_second_node moment_y_second_node moment_z_second_node ...*

After the calculation, this record will be filled with the forces and moments of a beam in the local beam axes *x*, *y*, *z*.

The *index* specifies the beam element number.

Attention: the values at the first node have a minus in their definition as compared with the values in the second node. By example in a beam number 20 with constant *z* moment of 10 you will find:

```
element_beam_force_moment 20 0. 0. 0. 0. 0. -10. 0. 0. 0. 0. 0. 10.
```

7.374 **element_contact_spring_direction** *index dirN_x dirN_y dirN_z dirT1_x dirT1_y dirT1_z dirT2_x dirT2_y dirT2_z*

In the input file, you can specify with this record the directions of a contact spring. If not specified, after the calculation this record will be filled with the used directions. The *index* specifies the spring element number.

7.375 **element_contact_spring_strain** *index strain_N strain_T1 strain_T2*

After the calculation, this record will be filled with the normal and tangential elongation in a contact_spring element. The *index* specifies the spring element number. The tangential strain *strain_T2* only is present in 3D.

7.376 **element_contact_spring_force** *index force_N force_T1 force_T2*

After the calculation, this record will be filled with the normal and tangential forces in a contact_spring element. The *index* specifies the spring element number. The tangential force *force_T2* only is present in 3D.

7.377 **element_dof** *index dof_0 dof_1 ...*

Unknowns as saved per element in the element nodes. First dof's in the first node. Then dof's in the second node. Etc.

This is done optionally by tochnog, only when needed for the calculation. The *index* specifies the element number.

7.378 **element_dof_initial** *index dof_0 dof_1 . . .*

When an element comes the first time to live, it assumes that it had in the past the dof's specified in this **element_dof_initial** record. You can either specify one value for each dof or you can specify values for the dof's for all nodes (specify first all dof's for the first node, then specify the dof's for the second node, etc.). The *index* specifies the element number.

This record will influence inertia terms (like mass acceleration, temperature capacity, etc). As an example you can set so the initial temperature of a part that is connected to the mesh at some time.

7.379 **element_dof_initial_specific_number** *index number*

With this record you can an initial value for one specific dof. The *number* specifies the dof number, for example **-velx** or **-sigxx**, etc. The initial value for the dof needs to be specified with **element_dof_initial_specific_value**. The *index* specifies the element number.

7.380 **element_dof_initial_specific_value** *index value_0 value_grad_x value_grad_y value_grad_z*

This specifies for the **element_dof_initial_specific_number** record the initial value. Here *value_0* is the value at coordinate $x = y = z = 0$, *value_grad_x* is the x-gradient, *value_grad_y* is the y-gradient and *value_grad_z* is the z-gradient. In 1D you only need to specify for the gradients the *value_grad_x* and in 2D you only need to specify for the gradients the *value_grad_x* and *value_grad_y*. As special option you can specify no gradients at all, and then a constant value in space of size *value_0* will be used.

7.381 **element_empty** *index switch*

If Tochnog believes an element is empty, then it will set automatically *switch* to **-empty** for **element_empty**.

7.382 **element_geometry** *index geometry_set*

This data item specifies for element *index* a geometrical set number *geometry_set*. Elements with the same geometrical set number together form a geometry, which can be referenced by functionality selecting elements by a geometry. The syntax for referring is **-element_geometry geometry_set**.

A typical application would be changing material data (groups) in time for different sets of elements. In the example below element 1 belongs to geometrical set 10. The elements of geometrical set 10 get in time respectively groups 100, 101, 102 and 103.

```

element 1 -bar2 1 2
element 2 -bar2 2 3
element_geometry 1 10

```

```

element_geometry 2 20
...
area_element_group_sequence_time 11 0. 1. 2. 3.
area_element_group_sequence_geometry 11 -element_geometry 10
area_element_group_sequence_element_group 11 100 101 102 103
...
area_element_group_sequence_time 12 0. 1. 2. 3.
area_element_group_sequence_geometry 12 -element_geometry 20
area_element_group_sequence_element_group 12 200 201 202 203
...

```

The **element_geometry** cannot be used in a **geometry_set**.

7.383 **element_geometry_present** *index geometry_item_name_0 geometry_item_index_0 geometry_item_name_1 geometry_item_index_1 ...*

This record lists for element *index* the geometries in which it is present. So it is a print record only, for checking if the geometries include exactly the elements that you want. You can switch on or off filling of these records by setting **print_element_geometry_present** to **-yes** or **-no**.

7.384 **element_group** *index element_group*

This data item is specified which element data items should be taken for the element *index*. Example: elements 0 and 1 get density 1024 while element 2 gets density 1236

```

element 0 0 1 2
element 1 1 2 3
element 2 2 3 4
...
element_group 0 1
element_group 1 1
element_group 2 2
...
density 1 1024.
density 2 1236.

```

If no **element_group** records are specified, all element data should use *index* is 0.

See also **area_element_group** and **element_geometry**.

7.385 **element_hinge_force** *index force*

After the calculation, this record will be filled with the normal force in a hinge element. The *index* specifies the hinge element number.

7.386 **element_hinge_moment** *index moment*

After the calculation, this record will be filled with the moment in a hinge element. The *index* specifies the hinge element number.

7.387 **element_hinge_plasti_status** *index status*

After the calculation, this record will be filled with the plastic status in a hinge element. The status is either **-elastic** of **-plastic**. The *index* specifies the hinge element number.

7.388 **element_hinge_rotation** *index moment*

After the calculation, this record will be filled with the rotation in a hinge element. The *index* specifies the hinge element number.

7.389 **element_interface_intpnt_direction** *index normal_x_0 normal_y_0 normal_z_0 first_tangential_x_0 first_tangential_y_0 first_tangential_z_0 second_tangential_x_0 second_tangential_y_0 second_tangential_z_0 ...*

After the calculation this record will be filled with the direction vectors in interface element. Here *normal_x_0* is the x-component of the normal direction in the first integration point, etc.

7.390 **element_interface_intpnt_gap_status** *index status*

After the calculation, this record will be filled with the gap status in an interface element. The status is either **-opened** of **-closed**. The *index* specifies the interface element number.

7.391 **element_interface_intpnt_materi_tension_status** *index status*

After the calculation, this record will be filled with the materi tension status in an interface element. The status is either **-opened** of **-closed**. The *index* specifies the interface element number.

7.392 **element_interface_intpnt_strain** *index strain,normal,0 strain,shear,first,0 strain,shear,second,0 strain,normal,1 strain,shear,first,1 strain,shear,second,1 ...*

After the calculation, this record will be filled with the normal strain, the first shear strain and second shear strain in the integration points of an an interface element. The values with subscript 0 are for the first integration point; The values with subscript 1 are for the second integration point; etc. For a 2D interface element the second shear strain will not be set.

In fact, the normal strain is the normal displacement difference, and the shear strains are half of the shear displacement differences.

This **element_interface_intpnt_strain** record will only be filled if **materi_strain_total** is initialised. The *index* specifies the interface element number.

7.393 element_interface_intpnt_strain_average *index strain,normal,0 strain,shear,first,0 strain,shear,second,0*

Average of **element_interface_intpnt_strain**.

7.394 element_interface_intpnt_stress *index stress,normal,0 stress,shear,first,0 stress,shear,second,0 stress,normal,1 stress,shear,first,1 stress,shear,second,1 ...*

After the calculation, this record will be filled with the normal stress, the first shear stress and the second shear stress in the integration points of an interface element. The values with subscript 0 are for the first integration point; The values with subscript 1 are for the second integration point; etc. For a 2D interface element the second shear stress will not be set.

The *index* specifies the interface element number.

See **control_reset_interface** on how to reset strains and stresses somewhere in a calculation.

7.395 element_interface_intpnt_stress_average *index stress,normal,0 stress,shear,first,0 stress,shear,second,0*

Average of **element_interface_intpnt_stress**.

7.396 element_intpnt_dof *index dof_0 dof_1 ...*

Unknowns as saved per element in the element integration points. The *index* specifies the element number.

7.397 element_intpnt_h *index ...*

This record is meant for printing only. It contains for each node of the element the value of the interpolation polynomial in the integration points.

7.398 element_intpnt_iso_coord *index ...*

This record is meant for printing only. It contains for each node of the element the value of the isoparametric coordinates in the integration points.

7.399 element_intpnt_materi_plasti_hardsoil_gammap_initial *index gammap_initial.integration_point_1 ...*

See theory section on hardsoil.

7.400 **element_intpnt_materi_undrained_pressure** *index undrained_total_pressure*

Total pressure from undrained analysis. See **group_materi_undrained_capacity**.

7.401 **element_intpnt_method** *index method*

This record is meant for printing only. It shows the space integration method that is actually used for element *index*. See also **group_integration_method**.

7.402 **element_intpnt_npoint** *index npoint*

This record is meant for printing only. It shows the number of space integration method points that are actually used for element *index*. See also **group_integration_points**.

7.403 **element_intpnt_plasti_laminate0_mohr_coul_status** *index status*

This record is meant for printing only. It gives for all integration points of an element the *status* of the mohr-coulomb yield rule of laminate 0. The *status* can be either **-elastic** or **-plastic**. For other laminates the records are **element_intpnt_plasti_laminate1_mohr_coul_status** etc.

The *index* is the element number.

7.404 **element_intpnt_plasti_laminate0_tension_status** *index status*

This record is meant for printing only. It gives for all integration points of an element the *status* of the tension cutoff yield rule of laminate 0. The *status* can be either **-elastic** or **-plastic**. For other laminates the records are **element_intpnt_plasti_laminate1_status_status** etc.

The *index* is the element number.

7.405 **element_materi_plasti_laminate0_apply** *index switch*

If *switch* is set to **-yes**, laminate 0 of the multilaminate model will be applied for the element with number *index* (if the laminate is specified in the element group data). If *switch* is set to **-no**, laminate 0 of the multilaminate model will not be applied for the element with number *index*. Default, if **element_materi_plasti_laminate0_apply** is not specified for an element then the *switch* is set to **-yes**.

For other laminates, **element_materi_plasti_laminate1_apply** should be specified.

7.406 **element_materi_plasti_laminate0_direction** *index dir_x dir_y dir_z*

If this record is specified, laminate 0 of the multilaminate model of the element with number *index* gets *dir_x dir_y dir_z* as normal for the multilaminate plane. This **element_materi_plasti_laminate0_direction** overrides the presence, if any, of the **group_materi_plasti_laminate0_direction** record for the element group.

7.407 **element_middle** *index middle_x middle_y middle_z*

After the calculation, this record will be filled with the middle coordinates of an element. The *index* specifies the element number.

7.408 **element_print_group_data_values** *index ...*

Values as required by **print_group_data**. The first value as required by **print_group_data** is placed in the first value of **element_print_group_data_values**. The second value as required by **print_group_data** is placed in the second value of **element_print_group_data_values**. Etc. Please realise that some group data requires more than one value, so that more than one value is filled in the **element_print_group_data_values** record.

7.409 **element_spring_force** *index force*

After the calculation, this record will be filled with the force in a spring element. The *index* specifies the spring element number.

7.410 **element_spring_strain** *index strain*

After the calculation, this record will be filled with the strain in a spring element. In fact the strain in a spring element is the elongation of the spring. The *index* specifies the spring element number.

In case you perform a geotechnical analysis and want to set all strains in the model to 0 after gravity has been imposed, then do a **control_data_delete** on all **element_spring_strain** records. In such way the **element_spring_strain** records will contain in the remaining part of the calculation strains relative to the gravity status.

7.411 **element_truss_direction** *index dir_x dir_y dir_z*

After the calculation, this record will be filled with the direction of a truss in space. The *index* specifies the truss element number.

7.412 **element_truss_force** *index force*

After the calculation, this record will be filled with the normal force in a truss element. The *index* specifies the truss element number.

7.413 **element_truss_strain** *index strain*

After the calculation, this record will be filled with the strain in a truss element (length increase divided by length). The *index* specifies the truss element number.

7.414 **element_truss_strain_temperature** *index strain*

After the calculation, this record will be filled with the normal thermal strain in a truss element (thermal length increase divided by length). The *index* specifies the truss element number.

7.415 **element_volume** *index volume*

This record contains the volume of the isoparametric element number *index* after the calculation. In fact for 1D elements it contains the element length, for 2D elements it contains the element area, and for 3D elements it contains the element volume.

7.416 **force_edge** *index force_0 force_1 ...*

Distributed edge forces. These distributed forces are translated into equivalent nodal force terms on the edges of elements. You should specify a force term for each direction. Also the record **force_edge_geometry** should be specified, and optionally the records **force_edge_factor** and **force_edge_time** can be specified.

Attention: if this **force_edge** option is used INSIDE a FE mesh, then the elements on each side of the geometry will get the force. So you may need to specify only half of the physical force value.

Attention: this option is only available for linear and quadratic isoparametric elements.

7.417 **force_edge_element** *index element_0 element_1 ...*

Selects the element for which the **force_edge** record with the same *index* should be applied.

7.418 **force_edge_element_group** *index element_group_0 element_group_1 ...*

Selects the element group for which the **force_edge** record with the same *index* should be applied.

7.419 **force_edge_element_node** *index element node_0 node_1 ...*

Selects the element and local node numbers for which the **force_edge** record with the same *index* should be applied.

7.420 **force_edge_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge** record with the same *index* should be applied.

7.421 **force_edge_factor** *index a_0 a_1 ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if $n=2$ the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if $n=5$ the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if $n=8$ the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.422 **force_edge_geometry** *index geometry_entity_name geometry_entity_index*

Selects the area for which the **force_edge** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.423 **force_edge_node** *index node_0 node_1 ...*

Selects the nodes for which the **force_edge** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.424 **force_edge_node_factor** *index factor_0 factor_1 ...*

Nodal multiplication factors with which the force of **force_edge** will be applied to the nodes of **force_edge_node**. You need to specify a factor for each node. Here *factor_0* is the multiplication factor for the first node, etc.

7.425 **force_edge_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

The **force_edge** record with the same *index* is imposed with the sum of the sine functions; the first sine function has frequency *freq_0* and amplitude *amp_0*, the second sine function has frequency *freq_1* and amplitude *amp_1*, etc.. The sine functions start at time 0. More general behavior in time can be imposed by using **force_edge_time** records. For a specific *index* only one of **force_edge_sine** and **force_edge_time** can be specified.

The sine loads will be only imposed after *start_time*, and only up to *end_time*.

More general time behavior can be specified with **force_edge_time**.

7.426 **force_edge_time** *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge** record with the same *index* is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, and the **force_edge_sine** record is not specified, the force is applied at all times with a factor 1.

If no external forces like **force_edge_time** are specified, the internal element forces become zero at free edges to satisfy equilibrium. This causes, for example, temperature gradients to become

zero at free edges in heat problems.

7.427 **force_edge_normal** *index force*

Distributed normal force in the direction of the outward normal at the edge of a element. This distributed term is translated into equivalent nodal force terms on the edges of elements. Also the record **force_edge_normal_geometry** should be specified, and optionally the record **force_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this **force_edge_normal** option is used INSIDE a FE mesh, then the elements on each side will get the force. So the total force will normally become zero since the normals of the elements at the side of the geometry are opposite.

7.428 **force_edge_normal_element** *index element_0 element_1 ...*

Restricts the element to which the **force_edge_normal** record with the same *index* should be applied.

7.429 **force_edge_normal_element_node** *index element node_0 node_1*

Selects the element and local node numbers for which the **force_edge_normal** record with the same *index* should be applied.

7.430 **force_edge_normal_element_group** *index element_group_0 element_group_1 ...*

Restricts the element group to which the **force_edge_normal** record with the same *index* should be applied.

7.431 **force_edge_normal_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_normal** record with the same *index* should be applied.

7.432 **force_edge_normal_factor** *index a₀ a₁ ... a_{n-1}*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_normal** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if n=2 the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if n=5 the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6

values). By example if $n=8$ the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.433 **force_edge_normal_geometry** *index geometry_entity_name geometry_entity_index*

Selects the area for which the **force_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.434 **force_edge_normal_node** *index node_0 node_1 node_2 ...*

Selects the nodes for which the **force_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.435 **force_edge_normal_node_factor** *index factor_0 factor_1 ...*

Nodal multiplication factors with which the force of **force_edge_normal** will be applied to the nodes of **force_edge_normal_node**. You need to specify a factor for each node. Here *factor_0* is the multiplication factor for the first node on the side, etc.

7.436 **force_edge_normal_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Same as **force_edge_sine**, now for normal edge loads however.

7.437 **force_edge_normal_time** *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_normal** record with the same *index* is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

7.438 **force_edge_projected** *index force ph(0,0,0) ph_grad_x ph_grad_y ph_grad_z pv(0,0,0) pv_grad_x pv_grad_y pv_grad_z factor_normal factor_tangential vertical_dir_downward_x vertical_dir_downward_y vertical_dir_downward_z tunnel_dir_x tunnel_dir_y tunnel_z*

Distributed projected force on the edge of a element. This distributed term is translated into equivalent nodal force terms on the edges of elements.

This record typically can be used to model soil normal and tangential loading on tunnels. With *ph(0,0,0)* you specify the horizontal ground stress at $x=0, y=0, z=0$. With *ph_grad_x*, *ph_grad_y* and *ph_grad_z* you specify the gradients of the horizontal stress (such that a linear horizontal stress field can be modeled). With *pv(0,0,0)* you specify the vertical ground stress at $x=0, y=0, z=0$. With

pv_grad_x, pv_grad_y and pv_grad_z you specify the gradients of the vertical stress (such that a linear vertical stress field can be modeled).

The vertical and horizontal stresses are projected on the edge of the element so that the radial stress sig_radial and the tangential stress sig_tangential of the edge of the element are obtained. You can decide to apply the radial stress sig_radial only with a factor factor_normal (between 0 and 1). Likewise, you can decide to apply the tangential shear stress sig_tangential only with a factor factor_tangential (between 0 and 1).

As extra information for Tochnog to determine the correct radial stress and tangential shear stress on the edge of an element you need to specify the downward vertical direction with vertical_dir_downward_x, vertical_dir_downward_y and vertical_dir_downward_z.

Only in 3D, you also need to specify the length direction of the tunnel axis with tunnel_dir_x, tunnel_dir_y and tunnel_z.

In 2D you should not specify the 3D information ph_grad_z, pv_grad_z, vertical_dir_downward_z, tunnel_dir_x, tunnel_dir_y and tunnel_z.

Also the record **force_edge_projected_geometry** should be used to specify where the force should be applied, and optionally the record **force_edge_projected_time** can be specified.

Attention: notice that horizontal soil stress in length direction of the tunnel is not included.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this **force_edge_projected** option is used INSIDE a FE mesh, then the elements on each side will get the force. So the total force will protectedly become zero since the projected of the elements at the side of the geometry are opposite.

7.439 **force_edge_projected_element** *index element_0 element_1 ...*

Restricts the element to which the **force_edge_projected** record with the same *index* should be applied.

7.440 **force_edge_projected_element_node** *index element node_0 node_1 ...*

Selects the element and local nodes for which the **force_edge_projected** record with the same *index* should be applied.

7.441 **force_edge_projected_element_group** *index element_group_0 element_group_1 ...*

Restricts the element group to which the **force_edge_projected** record with the same *index* should be applied.

7.442 **force_edge_projected_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_projected** record with the same *index* should be applied.

7.443 **force_edge_projected_factor** *index a₀ a₁ ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_projected** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if n=2 the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if n=5 the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if n=8 the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.444 **force_edge_projected_geometry** *index geometry_entity_name geometry_entity_index*

Selects the area for which the **force_edge_projected** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed force. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.445 **force_edge_projected_node** *index node_0 node_1 node_2 ...*

Selects the nodes for which the **force_edge_projected** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.446 **force_edge_projected_node_factor** *index factor₀ factor₁ ...*

Nodal multiplication factors with which the force of **force_edge_projected** will be applied to the nodes of **force_edge_projected_node**. You need to specify a factor for each node. Here *factor₀* is the multiplication factor for the first node, etc.

7.447 **force_edge_projected_sine** *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to **force_edge_sine**, now for projected edge loads however.

7.448 **force_edge_projected_time** *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_projected** record with the same index is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

7.449 **force_edge_water** *index switch*

If *switch* is set to **-yes**, distributed water pressure force is added to the model. This distributed term is translated into equivalent nodal force terms on the edges of elements. The distributed force is automatically calculated as $\text{density_water} \cdot g \cdot \Delta z$ where g is the gravitational acceleration, and Δz is the distance to the phreatic level. The water pressure force acts normal to the element edge, in inward direction. You need to specify also **force_edge_water_geometry**.

The water density is given by **groundflow_density**. The gravity acceleration is given by the vertical component of **force_gravity**. The water height is relative to the water height is given by **groundflow_phreatic_level**.

Attention: if this **force_edge_water** option should be used with care INSIDE a FE mesh.

The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.450 **force_edge_water_element** *index element_0 ...*

Selects the element for which the **force_edge_water** record with the same *index* should be applied.

7.451 **force_edge_water_element_group** *index element_group_0 ...*

Selects the element groups for which the **force_edge_water** record with the same *index* should be applied.

7.452 **force_edge_water_element_node** *index element node_0 node_1 ...*

Selects the element and local nodes for which the **force_edge_water** record with the same *index* should be applied.

7.453 **force_edge_water_element_side** *index element_0 element_1 ... side*

Selects the elements and local side number for which the **force_edge_water** record with the same *index* should be applied.

7.454 **force_edge_water_factor** *index a_0 a_1 ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for **force_edge_water** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if $n=2$ the polynomial is $a_0 + a_1x + a_2y$ (specify 3 values). By example if $n=5$ the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2$ (specify 6 values). By example if $n=8$ the polynomial is $a_0 + a_1x + a_2x^2 + a_3y + a_4y^2 + a_5x^2y + a_6x^2y^2 + a_7x^2y^2 + a_8x^2y^2$ (specify 9 values).

7.455 **force_edge_water_geometry** *index geometry_item_name geometry_item_index*

Selects the area for which the **force_edge_water** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed water pressure force.

7.456 **force_edge_water_node** *index node_0 node_1 ...*

Selects the nodes for which the **force_edge_water** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.457 **force_edge_water_time** *index time load time load ...*

This record specifies a diagram which contains the factors with which the **force_edge_water** record with the same *index* is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the force is applied at all times with a factor 1.

7.458 **force_gravity** *g_x g_y g_z*

Gravitational acceleration.

In 1D, only the gravity in x-direction needs to be specified. In 2D, the gravity in x-direction and y-direction needs to be specified. In 3D, the gravity in x-direction, y-direction and z-direction needs to be specified.

See also **force_gravity_time**.

7.459 **force_gravity_geometry** *geometry_item_name geometry_item_index*

With this record you can specify a geometrical entity on which the gravity force should be used. Only elements inside the geometry get the gravity force.

If this record is not specified all elements can get the gravity force.

See also **force_gravity_time**.

7.460 **force_gravity_time** *time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **force_gravity** record is applied. This allows you to impose the gravity on a structure slowly, which might be needed for path dependent problems. Outside the specified time range a factor 0 is used.

If this record is not specified, the gravity is applied at all times with a factor 1.

7.461 **force_volume** *index force_0 force_1 ...*

Distributed volume forces for each direction. Here *force_0* is the distributed force in the x-direction, etc. Consider the example with distributed volume force in x-direction for a 2D material:

force_volume 0 1.0.

The **force_volume** record can be used in **dependency_diagram** records (just like element group data)/

See also **force_volume_factor**, **force_volume_geometry**, and **force_volume_time**.

7.462 **force_volume_element** *index element_0 element_1 ...*

Specifies the elements for which the **force_volume** record with the same *index* should be applied.

7.463 **force_volume_element_group_0** *element_group_1 ... index element_group*

Specifies the element group for which the **force_volume** record with the same *index* should be applied.

7.464 **force_volume_factor** *index a_0 a_1 ... a_n*

This polynomial gives a factor which is used as a multiplication factor for **force_volume** records (with the same index). In this way, you can obtain coordinate dependent forces.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if n=2 the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if n=5 the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if n=8 the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.465 **force_volume_geometry** *index geometry_item_name geometry_item_index*

Specifies the area for which the **force_volume** record with the same *index* should be applied. For example, **-geometry_quadrilateral 1** can be used in 2D, indicating that the elements on quadrilateral 1 get the distributed force.

If both the **force_volume_element** and **force_volume_geometry** are not specified, then a geometry which encloses the whole model will be applied.

7.466 force_volume_sine *index start_time freq_0 amp_0 freq_1 amp_1 ...*

Same as **force_volume_sine**, now for volume loads however.

7.467 force_volume_time *index time load time load ...*

This record specifies a multi-linear diagram which contains the factors with which the **force_volume** record with the same index is applied.

If this record is not specified, the force is applied at all times with a factor 1.

7.468 geometry_factor *index factor_0 ...*

This sets for some geometries extra factors which are used for the **bounda_dof**, **bounda_force** and **force_edge_*** records. For a **geometry_line** either 2 or 3 factors should be specified; 2 factors define a linear variation where the factors hold at the start and end of the line respectively; 3 factors define a parabolic variation where the factors hold at the start, at the middle and at the end of the line respectively. For a **geometry_triangle** 3 factors should be specified (a linear variation with factors for the first, second and third corner point respectively). For a **geometry_quadrilateral** 4 factors should be specified (a linear variation with factors for the first, second, third and fourth corner point respectively). For a **geometry_point** 1 factor should be specified; a multiplication with a half sine wave will be used, with the specified factor in the middle (exactly at the point) ceasing to factor 0 at a distance *tolerance* from the point,

In the example below, node 2 will get temperature 20*1.6 and node 3 will get temperature 20*2.2.

```
...
number_of_space_dimensions 2
condif_temperature
...
end_initia
node 2 0.2 0
node 3 0.4 0.
...
geometry_line 1 0. 0. 1. 0. 0.01
geometry_factor 1 1. 4.
bounda_dof 0 -geometry_line 1 -temp
bounda_time 0 0. 20. 1.e6 20.
...
end_data
```

7.469 geometry_boundary *index switch*

With this record you can restrict a geometry to the boundary of the mesh, or to the inside of the mesh. If *switch* is set to **-yes** only nodes which are at the boundary of the mesh are actually used for the geometry with the same index. If *switch* is set to **-no** only nodes which are not at the boundary of the mesh are actually used for the geometry with the same index.

Attention: for this option to work correctly, the mesh should not contain badly shaped elements. See the section at the end of this manual for more information on bad element shapes.

7.470 **geometry_bounda_sine_x** *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in x-direction. The size of the factor is $\sin(a + b * x)$.

7.471 **geometry_bounda_sine_y** *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in y-direction. The size of the factor is $\sin(a + b * y)$.

7.472 **geometry_bounda_sine_z** *index a b*

This sets, for the geometrical entity with the same index an extra factor which is used for the **bounda_dof** and the **bounda_force** records. The factor gives a sinus variation in z-direction. The size of the factor is $\sin(a + b * z)$.

7.473 **geometry_brick** *index x_c y_c z_c l_x l_y l_z tolerance*

This data item defines a brick in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is $x_c y_c z_c$. The length in respectively x , y and z direction are $l_x l_y l_z$. All **node** within a distance *tolerance* are considered to be part of the brick.

7.474 **geometry_circle** *index x_c y_c ... radius tolerance*

This data item defines a circle in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is $x_c y_c$. In 2D you need to specify $x_c y_c radius tolerance$. In 2D all **node** within a distance *tolerance* of the radius are considered to be part of the circle. In 3D you need to specify $x_c y_c z_c normal_x normal_y normal_z radius tolerance$, where $normal_x normal_y normal_z$ specifies the direction normal to the surface. In 3D all **node** within a distance *tolerance* of the circle surface are considered to be part of the circle.

7.475 **geometry_circle_part** *index x_c y_c angle_start angle_end radius tolerance*

This data item defines a circle in 2D space. Other data items can check if nodes are located on this geometry. The coordinate of the center is $x_c y_c$. All **node** within a distance *tolerance* of the radius are considered to be part of the circle. The circle part starts at angle *angle_start*, measured in radians from the positive x-axis. The circle part ends at angle *angle_end*, measured in radians from the positive x-axis.

7.476 **geometry_circle_segment** *index x_c y_c radius side_x side_y tolerance*

This data item defines a circle segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is $x_c y_c$. If *side_x* is set to a positive value, say +1., then only x-values larger than x_c are considered to be part of the geometry. If *side_x* is set to a negative value, say -1., then only x-values smaller than x_c are considered to be part of the

geometry. If *side_x* is set to 0 , then all x-values are considered to be part of the geometry. Likewise remarks hold for y-values. All **node** within a distance *tolerance* of the radius are considered to be part of the circle segment.

7.477 **geometry_cylinder** *index x_0 y_0 z_0 x_1 y_1 z_1 radius tolerance*

This data item defines a cylinder segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center point at the bottom is *x_0 y_0 z_0*. The coordinate of the center point at the top is *x_1 y_1 z_1*. The cylinder can only be used in 3D. All **node** within a distance *tolerance* of the radius are considered to be part of the cylinder.

7.478 **geometry_cylinder_part** *index x_0 y_0 z_0 x_1 y_1 z_1 radius angle_start_0 angle_end_0 angle_start_1 angle_end_1 ... tolerance*

This data item defines parts of a cylinder in space. Other data items can check if nodes are located on this geometry.

The *index x_0 y_0 z_0 x_1 y_1 z_1 radius* are the same as in **geometry_cylinder**.

The *angle_start_0 angle_end_0* defines the first valid part of the cylinder, where *angle_start_0* is the start angle of the part and *angle_end_0* is the end angle. The angles are measured in the x-y plane, starting from the positive x-axis towards the positive y-axis. Likewise, the *angle_start_1 angle_end_1* defines a second valid part of the cylinder. You should define at least one valid part, and optionally you can specify several valid parts.

Start angles and end angles should be non-negative. End angles should be larger than start angles.

Angles will be measured relative to the vector as specified in **geometry_cylinder_part_start_vector**, if that vector is specified. This **geometry_cylinder_part_start_vector** should be specified perpendicular to the cylinder axes. This **geometry_cylinder_part_start_vector** should be exactly in the middle of the angle range that you want to select. With **geometry_cylinder_part_start_vector** only one angle range is allowed, and the start angle should be 0. All nodes with an angle smaller or equal to the end angle are accepted as valid (thus, you get a total angle range of twice the end angle size as valid range).

If **geometry_cylinder_part_start_vector** is not specified, the **geometry_cylinder_part** should be either along the x-direction, y-direction or z-direction; then the angle is measured relative to the axes (by example for a cylinder along the z-direction the angle starts at the x-axes).

All **node** within a distance *tolerance* of the radius and inside a valid part are considered to be part of the cylinder part.

7.479 **geometry_cylinder_part_start_vector** *index v_x v_y v_z*

See **geometry_cylinder_part**.

7.480 **geometry_cylinder_segment** *index x_0 y_0 z_0 x_1 y_1 z_1 radius side_x side_y side_z tolerance*

This data item defines a cylindrical segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center point at the bottom is *x_0 y_0 z_0*. The

coordinate of the center point at the top is $x_1 y_1 z_1$. If *side_x* is set to a positive value, say +1., then only x-values larger than x_c are considered to be part of the geometry. If *side_y* is set to a negative value, say -1., then only x-values smaller than x_c are considered to be part of the geometry. If *side_x* is set to 0, then all x-values are considered to be part of the geometry. Likewise remarks hold for y- and z-values. The cylinder segment can only be used in 3D. All **node** within a distance *tolerance* of the radius are considered to be part of the cylinder.

7.481 **geometry_exclude** *index geometry_item_name_0 geometry_item_index_0 geometry_item_name_1 geometry_item_index_1 ...*

With this record you can exclude geometries from the geometry with the same index. The next 2D example excludes a circular area with radius 0.3 inside a quadrilateral:

```
...
geometry_quadrilateral 10 0. 0. 1. 0. 0. 1. 1.
geometry_exclude 10 -geometry_point 20

geometry_point 20 0.5 0.5 0.3
...
```

You are not allowed to let a **geometry_*** use a **geometry_exclude** which contains itself.

7.482 **geometry_element_geometry** *index element_geometry_0 element_geometry_1 ...*

Similar to **geometry_element_group**, but now using **element_geometry** i.s.o. **element_group** however.

7.483 **geometry_element_geometry_method** *index method*

Similar to **geometry_element_group_method**.

7.484 **geometry_element_group** *index element_group_0 element_group_1 ...*

With this record you can restrict the geometry as specified in the geometry record with the same *index*. For example for the geometry as specified by

```
...
geometry_quadrilateral 10 ...
geometry_element_group 10 ...
...
```

nodes which are located on the **geometry_quadrilateral 10**, but at the same time are also a node of elements of one of the specified element groups *element_group_0 element_group_1* etc., belong to the geometry. Nodes which are not a node of elements of one of the groups do not belong to the geometry, even if such nodes are located on the **geometry_quadrilateral 10**.

See also **geometry_element_group_method**.

7.485 **geometry_element_group_method** *index method*

With this record you can set the *method* that the **geometry_element_group** record uses. If *method* is set to **-all** then a node should be attached to all the specified element groups, to be part of the geometry. If *method* is set to **-any** then a node should be attached to any of the specified element groups, to be part of the geometry. If *method* is set to **-only** then a node should be attached to only the specified element groups, to be part of the geometry. Default, if *method* is not specified then **-any** is assumed.

7.486 **geometry_ellipse** *index x_c y_c a b tolerance*

The coordinate of the center is *x_c y_c*. The equation for the ellipse is:

$$\left(\frac{x - x_c}{a}\right)^2 + \left(\frac{y - y_c}{b}\right)^2 = 1$$

Other data items can check if nodes are located on this geometry. The ellipse can only be used in 2D. All **node** within a distance *tolerance* of the ellipse are considered to be part of the ellipse.

7.487 **geometry_hexahedral** *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3 x_4 y_4 z_4 x_5 y_5 z_5 x_6 y_6 z_6 x_7 y_7 z_7*

This data item defines a hexahedral in space. Other data items can check if nodes are located on this geometry (everything inside the hexahedral belongs to the geometry). The coordinates of the corner points are *x_0 y_0 z_0* etc.. The points of the hexahedral should be specified in the correct order; the order is clarified in the example below.

Example

```
...
number_of_space_dimensions 3
...
geometry_hexahedral 0 0. 0. 0. 1. 0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 1. 1. 0. 1.
0. 1. 1. 1. 1. 1.
...
```

Notice the order in which the points are to be specified.

7.488 **geometry_line** *index x_0 y_0 z_0 x_1 y_1 z_1 radius*

This data item defines a line in space. Other data items can check if nodes are located on this geometry. Coordinates of the end points are denoted by *x_0*, etc.. In 1D, only the *x*-coordinates should be specified, etc.. All **node** within a distance *radius* are considered to be part of the line.

In the example, a line in 2D space is defined and is used by a **convection_geometry** record (nodes located on the line will convect heat)

```

...
geometry_line 2 1. 0. 1. 1. 0.01
...
group_condif_convection_edge_normal_geometry 0 -geometry_line 2
...

```

7.489 geometry_line_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the line in direction of the line. Typically try $1.e - 3$ for *iso_tolerance*.

7.490 geometry_list *index number_0 number_1 ...*

This is a list of numbers which can be used in geometry selection options.

By example

```

...
geometry_list 10 1 45 43 26 27
...
bounda_dof 200 -geometry_list 10 ... (set the boundary condition on the nodes of
the list)
...

```

7.491 geometry_method *index method*

For selecting elements with a geometry entity you can set the *method* either to **-all**, **-any** or **-average**. With **-all** all nodes of an element should be inside the geometry entity for the element to be selected (completely inside). With **-any** any node of an element should be inside the geometry entity for the element to be selected (at least partially inside). With **-average** the middle coordinate of an element should be inside the geometry entity for the element to be selected. Default if this record is not specified the *method* is set to **-all**.

7.492 geometry_point *index x y z radius*

This data item defines a point in space. Other data items can check if nodes are located on this geometry. The coordinate of the point is $x y z$. In 1D, only x should be specified, etc.. All **node** within a distance *radius* are considered to be part of the point.

7.493 geometry_polynomial *index a_0 a_1 ... a_n x_0 x_1 y_0 y_1 tolerance*

This data item defines a polynomial in space if 2D or 3D. Other data items can check if nodes are located on this geometry. In 2D it is the curve $y = a_0 + a_1x + a_2x^2 + \dots$. In 3D it is the surface $z = a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$. In 2D $x_0 - x_1$ defines the domain of x . In 3D $x_0 - x_1$ defines the domain of x and $y_0 - y_1$ defines the domain of y .

y. All **node** with a distance (that is the *y*-distance in 2D or the *z*-distance in 3D) not more than *tolerance* are considered to be part of the polynomial.

7.494 geometry_quadrilateral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3 tolerance*

This data item defines a quadrilateral in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are *x_0 y_0 z_0* etc.. In 2D, only *x_0, y_0* etc. should be specified etc.. The points of the quadrilateral should be specified in the correct order; the order is clarified in the example below.

In 2D all **node** inside the quadrilateral (the tolerance is neglected). In 3D all **node** within a distance *tolerance* are considered to be part of the quadrilateral (this is a brick with thickness *tolerance*). All **node** within a distance *tolerance* are considered to be part of the quadrilateral (in 2D this gives a quadrilateral with corners nodes specified by the corners points, in 3D this gives a brick corners nodes specified by the corners points and with thickness *tolerance*). Internally in TOCHNOG, the quadrilateral is divided into two **geometry_triangles**, which is only approximately true if the quadrilateral is twisted. Example

```
...
number_of_space_dimensions 2
...
geometry_quadrilateral 0 0. 0. 1. 0. 0. 1. 1. 1. 1.e-3
...
```

Notice the order in which the points are to be specified.

7.495 geometry_quadrilateral_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the quadrilateral in direction of the quadrilateral plane. Typically try $1.e - 3$ for *iso_tolerance* .

7.496 geometry_set *index geometry_entity_0 geometry_entity_index_0 geometry_entity_1 geometry_entity_index_1 ...*

This set combines a number of geometrical entities (e.g. **geometry_circle**, **geometry_line**, etc.) into a new entity. You cannot use another geometry set for the geometrical entities (that is, geometry sets cannot be nested).

Other data items can check if nodes are located on this geometry.

7.497 geometry_sphere *index x_c y_c z_c radius tolerance*

This data item defines a sphere in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is *x_c y_c z_c*. All **node** within a distance *tolerance* of *radius* are considered to be part of the sphere.

7.498 geometry_sphere_segment *index x_c y_c z_c radius side_x side_y side_z tolerance*

This data item defines a spherical segment in space. Other data items can check if nodes are located on this geometry. The coordinate of the center is x_c y_c z_c . If *side_x* is set to a positive value, say +1., then only x-values larger than x_c are considered to be part of the geometry. If *side_x* is set to a negative value, say -1., then only x-values smaller than x_c are considered to be part of the geometry. If *side_x* is set to 0, then all x-values are considered to be part of the geometry. Likewise remarks hold for y- and z-values.

All **node** within a distance *tolerance* of *radius* are considered to be part of the spherical segment.

7.499 geometry_tetrahedral *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3*

This data item defines a tetrahedral in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are x_0 y_0 z_0 etc..

7.500 geometry_triangle *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 tolerance*

This data item defines a triangle in space. Other data items can check if nodes are located on this geometry. The coordinates of the corner points are x_0 y_0 z_0 etc.. In 2D the z coordinates should not be specified. All **node** within a distance *tolerance* are considered to be part of the triangle (this gives a wedge with thickness $2tolerance$).

7.501 geometry_triangle_eps_iso *index iso_tolerance*

With this parameter you can ask Tochnog to accept points just outside the triangle in direction of the triangle plane. Typically try $1.e-3$ for *iso_tolerance*.

7.502 global_element_dof_apply *switch*

If you set **switch** to **-yes**, then dof's like strains, stresses, etc. will be saved in the element integration points in the records **element_intpnt_dof**. So, these dof's will actually not be averaged over global nodes, but each element remembers its own values for these dof's. This will be done for dof's like strains, stresses, etc. only. Other dof's like velocities, displacement field, temperature, etc. are not saved per element, but remain saved in the global nodes.

If you set **switch** to **-no**, then elements will actually use the averaged nodal results, and will not remember its own values.

Default, if **global_element_dof_apply** is not specified, **global_element_dof_apply** is set to **-yes**. See also **global_element_dof_from_node_dof**.

7.503 global_element_dof_from_node_dof *switch*

If **global_element_dof_apply** is set to **-yes**, and the **element_intpnt_dof** record does not exist, but **node_dof** records exist in the input file, you can either require that the **element_intpnt_dof** records will be initialised from the **node_dof** records, or will not be initialised from the **node_dof**

records. If you set *switch* to **-yes** the **element_intpnt_dof** records will be initialised from the **node_dof** records. If you set *switch* to **-no** the **element_intpnt_dof** records will not be initialised from the **node_dof** records. Default, if **global_element_dof_from_node_dof** is not specified, *switch* is set to **-no**.

7.504 **global_post_point** *node_type*

With this record you can determine how records like **post_point**, **control_print_dof_point** and **control_print_dof_line** are evaluated. If *node_type* is set to **-node** the current nodal coordinates for elements are used to determine for which material point inside elements the dof's should be determined; if you do an updated lagrange calculation in which the coordinates of nodes change, so the **node** records change, you get dof results for the material at the current moment presented on the point or line. If *node_type* is set to **-node_start_refined** the initial start nodal coordinates for elements are used to determine for which material point inside elements the dof's should be determined; thus you get dof results for the material at the initial start moment presented on the point or line.

Default, if this record is not set, *node_type* is set to **-node_start_refined**.

7.505 **groundflow_apply** *switch*

If *switch* is set to **-no**, then the groundflow equation is skipped, and all groundflow data is ignored. This is done for all timesteps.

7.506 **groundflow_consolidation_apply** *switch*

If *switch* is set to **-no**, then the material divergence part in the groundflow equation is skipped. This is done for all timesteps.

Default *switch* is **-no**.

7.507 **groundflow_density** ρ

Density of ground water.

7.508 **groundflow_flux_edge_normal** *index flux*

Distributed prescribed water flux in the direction of the outward normal at the edge of a element. This distributed flux is translated into equivalent nodal flux on the edges of elements. Also the record **groundflow_flux_edge_normal_geometry** should be specified, and optionally the record **groundflow_flux_edge_normal_time** can be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

Attention: if this option is used INSIDE a FE mesh, then the elements on each side will get the distributed flux. So the total water flux will normally become zero since the normals of the elements at the side of the geometry are opposite.

7.509 `groundflow_flux_edge_normal_element` *index element_0 element_1 ...*

Restricts the elements to which the `groundflow_flux_edge_normal` record with the same *index* should be applied.

7.510 `groundflow_flux_edge_normal_element_group` *index element_group_0 element_group_1 ...*

Restricts the element groups to which the `groundflow_flux_edge_normal` record with the same *index* should be applied.

7.511 `groundflow_flux_edge_normal_element_node` *index element node_0 node_1 ...*

Selects the element and local node numbers for which the `groundflow_flux_edge_normal` record with the same *index* should be applied.

7.512 `groundflow_flux_edge_normal_element_node_factor` *index factor_0 factor_1 ...*

Nodal multiplication factors with which the `groundflow_flux_edge_normal` will be applied to the element of `groundflow_flux_edge_normal_element_node`. You need to specify a factor for each node on the side. Here *factor₀* is the multiplication factor for the first node on the side, etc.

7.513 `groundflow_flux_edge_normal_element_side` *index element_0 element_1 ... side*

Selects the elements and local side number for which the `groundflow_flux_edge_normal` record with the same *index* should be applied.

7.514 `groundflow_flux_edge_normal_factor` *index a₀ a₁ ... a_n*

This data item defines a polynomial in space. This polynomial gives a factor which is used as a multiplication factor for `groundflow_flux_edge_normal` records (with the same index). In this way, you can obtain coordinate dependent water fluxes.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$

In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

We explain the logic in 3D with examples. By example if n=2 the polynomial is $a_0 + a_1 + a_2$ (specify 3 values). By example if n=5 the polynomial is $a_0 + a_1x + a_2 + a_3y + a_4 + a_5z$ (specify 6 values). By example if n=8 the polynomial is $a_0 + a_1x + a_2x^2 + a_3 + a_4y + a_5y^2 + a_6 + a_7z + a_8z^2$ (specify 9 values).

7.515 `groundflow_flux_edge_normal_geometry` *index geometry_entity_name geometry_entity_index*

Selects the area for which the `groundflow_flux_edge_normal` record with the same *index* should be applied. For example, `-geometry_line 1` can be used in 2D, indicating that the nodes on line 1 get the distributed flux. The total edge of an element must be inside the geometry for the force to become active. For 2D elements the border lines are edges. For 3D elements the border surfaces are edges.

7.516 `groundflow_flux_edge_normal_node` *index node_0 node_1 node_2 ...*

Selects the nodes for which the `groundflow_flux_edge_normal` record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.517 `groundflow_flux_edge_normal_sine` *index start_time end_time freq_0 amp_0 freq_1 amp_1 ...*

Similar to `force_edge_sine`, now for water flux however.

7.518 `groundflow_flux_edge_normal_time` *index time load time load ...*

This record specifies a diagram which contains the factors with which the `groundflow_flux_edge_normal` record with the same *index* is applied. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, the flux is applied at all times with a factor 1.

7.519 `groundflow_nonsaturated_apply` *index switch*

If *switch* is set to `-no`, then nonsaturated groundflow data (eg van Genuchten) will not be applied; only saturated data will be used. This is done for all timesteps.

Default *switch* is `-yes`.

7.520 `groundflow_phreatic_bounda` *switch*

If *method* is set to `-yes`, the phreatic level is used to automatically prescribe the hydraulic head of nodes which are located on or above the phreatic level.

Default, if `groundflow_phreatic_bounda` is not specified, *method* is set to `-yes`,

7.521 `groundflow_phreatic_level` ...

Groundwater level.

In a 1D calculation this record should be given *x* value of the groundwater level. The groundwater is below that *x*-value.

In a 2D calculation this record should be given sets of $x - y$ which specify the y level of the groundwater at several x locations; In 2D you need to give the $x - y$ sets as follows:

- specify $x - y$ sets for increasing x

In 3D the phreatic line is specified as follows. Denote the lowest x with x_0 , the next higher x with x_1 etc. Denote the lowest y with y_0 , the next higher y with y_1 etc. Denote the phreatic level z value for $x_i y_j$ with z_{ij} . Then give the following:

- $x_0 y_0 z_{00} x_1 y_0 z_{10}$ etc.
- $x_0 y_1 z_{01} x_1 y_1 z_{11}$ etc.
- etc.

In 3d, the number of points in x and y direction respectively should be set with nx and ny of the **groundflow_phreatic_level_n** record.

In nodes above the phreatic level the total pressure will be set to zero during the calculation.

As a special option in 2D and 3D, you can specify one value only, which sets a constant phreatic level of that value everywhere. In this special case, you do not need to specify **groundflow_phreatic_level_n**.

If you want to apply pore pressures directly following from the height under a phreatic level but not influenced by groundwater flow, then include a phreatic level and a boundary conditions for hydraulic head changes:

```
...
groundflow_phreatic_level ...
...
bounda_dof 20 ...-tpres
```

This has the advantage that the groundflow pressures don't enter the system of equations, so that for combined soil - groundwater analysis a more effective solution can be obtained for the system of equations.

7.522 groundflow_phreatic_level_n nx ny

See **groundflow_phreatic_level**.

7.523 groundflow_phreatic_level_static switch

If *switch* is set to **-yes**, total pressures (pore pressures) in nodes for which the **groundflow_phreatic_level** holds, will be set equal to the static pressure.

This is convenient if the phreatic line is located above the mesh part to which it belongs; then nodes of the mesh will not get a boundary condition, so that the correct hydraulic head can not be determined. And thus, it is necessary to determine the total pressure (pore pressure) from the difference of nodal coordinates and phreatic line height.

It is also convenient if you do not want to initialise and solve the hydraulic heads with the groundflow storage equation. This saves computer memory and CPU time.

In the **group_type** for elements which should get the static groundflow pressure you need to add **-groundflow**.

7.524 **groundflow_phreatic_level_multiple** *index* ...

The same as **groundflow_phreatic_level**, but now however several groundwater levels can be specified. For each **groundflow_phreatic_level_multiple** you should specify a separate value for *index*.

This option typically can be used if you have in vertical direction non-permeable layers separating the total domain in independent parts with each its own groundwater level.

You can specify with one of **groundflow_phreatic_level_multiple_element** or **groundflow_phreatic_level_multiple_element_group** or **groundflow_phreatic_level_multiple_node** the parts of the domain that belong to the groundwater level of **groundflow_phreatic_level_multiple** with the same index. Only one of these record can be used, you cannot combine them.

With **groundflow_phreatic_level_multiple_n** you specify *nx ny* in 3D again.

In the **group_type** for elements which should get the static groundflow pressure you need to add **-groundflow**.

7.525 **groundflow_phreatic_level_multiple_element** *index* element_0 element_1 ...

Element numbers for **groundflow_phreatic_level_multiple** with the same index.

7.526 **groundflow_phreatic_level_multiple_element_group** *index* element_group_0 element_group_1 ...

Element group numbers for **groundflow_phreatic_level_multiple** with the same index.

7.527 **groundflow_phreatic_level_multiple_element_geometry** *index* element_geometry_0 element_geometry_1 ...

Element geometry numbers for **groundflow_phreatic_level_multiple** with the same index.

7.528 **groundflow_phreatic_level_multiple_n** nx ny

See **groundflow_phreatic_level_multiple**.

7.529 **groundflow_phreatic_level_multiple_node** *index* node_0 node_1 ...

Node numbers for **groundflow_phreatic_level_multiple** with the same index.

7.530 **groundflow_phreatic_level_multiple_static** *index switch*

If *switch* is set to **-yes**, total pressures (pore pressures) in nodes for which the **groundflow_phreatic_level_multiple** holds, will be set equal to the static pressure.

This is convenient if the phreatic line is located above the mesh part to which it belongs; then nodes of the mesh will not get a boundary condition, so that the correct hydraulic head can not be determined. And thus, it is necessary to determine the total pressure (pore pressure) from the difference of nodal coordinates and phreatic line height.

It is also convenient if you do not want to initialise and solve the hydraulic heads with the groundflow storage equation. This saves computer memory and CPU time.

7.531 **groundflow_phreatic_only** *switch*

If *switch* is set to **-yes** groundflow data is removed for groups which are not part of **groundflow_phreatic_level_multiple_element_group** records. Thus only groundflow data is retained for groups for which a multiple phreatic level is defined.

7.532 **groundflow_phreatic_project** *switch*

If *switch* is set to **-yes**, the hydraulic head which is imposed on nodes above the phreatic level uses the project coordinate on the phreatic level (smallest distance); thus not simply the distance in vertical direction. For most calculations that gives better groundwater velocities.

Sometimes, however, it may be better to simply use the vertical direction of a node to the phreatic level; you can obtain that by setting *switch* to **-no**.

Default, it **groundflow_phreatic_project** is not specified, *switch* is set to **-yes**.

7.533 **groundflow_seepage_eps** *eps*

The *eps* specifies the tolerance if the groundflow seepage condition should be applied or not. If the inner product of the groundflow water flow direction with the normal outside the material is smaller then *eps*, the seepage status will be set to closed, and the total pressure condition will not be applied (so that the boundary is really closed for water flow). If not specified, *eps* is set to 0.1.

7.534 **groundflow_seepage_geometry** *index geometry_item_name geometry_item_index*

This record specifies an edge of the groundflow domain for which the groundwater is only allowed to flow outwards of the domain; flow into the domain is not allowed on that edge. The geometrical entity should be specified such that the normal of the geometry points outwards the material (so outwards the groundflow domain). This option comes handy when the point of groundwater flow exit is not known in advance of the calculation; it will be a result of the calculation instead.

Example:

```
...
groundflow_seepage_geometry 10 -geometry_line 100
...
```

bounda_dof 20 -geometry_line 100 -total_pressure
bounda_time 20 0.0

In this example the total pressure (pore pressure) is set to 0 on the geometry line number 100, to account for free air at that edge. Since at that edge water cannot enter the domain the seepage option is applied to that edge. The result of these combined options is that on nodes with outward flow a total pressure 0 boundary condition is imposed, whereas on other nodes no boundary conditions is imposed (so that the flow is 0 at those nodes). The transition point between these outflow nodes and nodes with zero flow will be found automatically as a result of the calculation.

7.535 **groundflow_seepage_node** *index node_0 node_1 ...*

This record does the same as the **groundflow_seepage_geometry** record, but now however you specify node numbers at which the seepage condition holds. The *node_0* is the first node number, the *node_1* is the second node number, etc.

7.536 **groundflow_total_pressure_limit** **limit**

With this record you can specify the maximum allowed total pressure value. Any higher value resulting from the groundflow equations will be cutoff to this value. Default the *limit* is set to 0.

7.537 **group_axisymmetric** *index switch*

If *switch* is set to **-yes**, the calculation becomes axi-symmetrical for the group *index*. Each specified *x* coordinate becomes a radius and *y* becomes the length (=vertical) direction. The *z*-direction is the axi-symmetric direction. Specify only non-negative *x* coordinates, i.e. define the computational domain in the right half-plane.

This option is only available for groups with isoparametric 1D elements (bar2, ...), or isoparametric 2D elements (tria3, quad4, ...), or for 2D interface elements (quad4 interface, ...) , or for the truss element (truss).

7.538 **group_beam_inertia** *index Iyy Izz J*

Bending and torsion properties for beam elements. Here *Iyy* is the area moment of inertia for bending along the local beam *y* axis, and *Izz* is the area moment of inertia for bending along the local beam *z* axis, and *J* is the polar moment of inertia for torsion along the local beam *x* axis.

See also **beam_rotation** in the initialisation part.

The *index* specifies the element_group, see **element_group**.

7.539 **group_beam_memory** *index memory_type*

Memory model for beam; either **-updated_linear**, **-updated** or **-total_linear**. The **-updated** model is a geometrically nonlinear model which takes large beam rotations into account. The *index* specifies the element_group, see **element_group**.

7.540 **group_beam_direction_z** *index dir_z,x dir_z,y dir_z,z*

This record specifies the local beam z direction in global space. If **group_beam_direction_z** is not specified in 2D then *0 0 1* will be used. If **group_beam_direction_z** is not specified in 3D then a arbitrary direction perpendicular to the beam length axes will be used.

The local beam axes will be placed in the **element_beam_direction** record after the calculation.

The *index* specifies the element_group, see **element_group**.

See also **group_beam_direction_z_reference_point** for automatic beam z-axis towards a reference point.

7.541 **group_beam_direction_z_reference_point** *index point_x point_y point_z*

This data record defines a reference point that allows you to influence the local beam z-direction. The local beam z-direction will be setup as follows:

- The length direction of the beam is determined, that is the local beam x-axis.
- A vector is taken from the beam middle point to the reference point.
- The part of this vector perpendicular to the length direction defines the local beam z-axis.

The above procedure ensures that the beam z-axis is perpendicular to the length direction, and that the z-axis points as much as possible to the reference point. As a typical example, you can use this option to take care that the local beam z-axis points to the middle of a tunnel, which is convenient if a tunnel lining with the local z-axis towards the tunnel middle; to do so specify the middle point of the tunnel axis as reference point *point_x point_y point_z*.

7.542 **group_beam_young** *index E*

Young's modulus for a beam (for bending moment calculation). The *index* specifies the element_group, see **element_group**.

7.543 **group_beam_shear** *index G*

Shear modulus for a beam (for torsion moment calculation). The *index* specifies the element_group, see **element_group**.

7.544 **group_condif_absorption** *index a*

Absorption coefficient. The *index* specifies the element_group, see **element_group**.

7.545 **group_condif_capacity** *index C*

Heat capacity. The *index* specifies the element_group, see **element_group**.

7.546 **group_condif_conductivity** *index k_x k_y k_z*

Heat conductivity in x, y and z direction respectively. As a special option you can also specify one value only, which then will be used in each direction. The *index* specifies the **element_group**, see **element_group**.

7.547 **group_condif_density** *index density*

Density for convection-diffusion equation. The *index* specifies the **element_group**, see **element_group**.

7.548 **group_condif_flow** *index beta₁ beta₂ beta₃*

Known flow field. In 1D only *beta₁* should be specified, etc. The *index* specifies the **element_group**, see **element_group**.

7.549 **group_contact_spring_direction** *index dirN_x dirN_y dirN_z*

Normal direction of a **contact_spring**. The *index* specifies the **element_group**, see **element_group**.

As an alternative, you can specify **element_contact_spring_direction** which allows for specification of the direction for each element separately.

As yet another alternative you can set *switch* in **group_contact_spring_direction_automatic** to **-yes**. Then the contact spring will automatically determine the directions.

7.550 **group_contact_spring_direction_automatic** *index switch*

See **group_contact_spring_direction**.

7.551 **group_contact_spring_plasti_cohesion** *index c*

The normal contact force F_N is not allowed to become larger than cohesion c in tension (positive values of F_N). If it would become larger, then the contact is broken, a gap is assumed and the contact force F_N is put to 0. To have really a positive F_N for extension of the contact spring, the order of the two nodes as specified in the **element** record for the contact spring should be correct.

Notice that when you use **control_mesh_generate_contact_spring** to obtain the contact spring elements, you are not sure what the first and what the second node of an element will be, and thus you should not use this **group_contact_spring_cohesion** record. Otherwise, it is not important what you use as first and second node, so that **control_mesh_generate_contact_spring** can be used safely.

If this **group_contact_spring_plasti_cohesion** is not specified, infinite cohesion is assumed.

The *index* specifies the **element_group**, see **element_group**.

7.552 `group_contact_spring_plasti_friction` *index f*

With this record you can specify a fixed friction coefficient for contact springs. If this record is not specified, a very large value for f will be applied.

The *index* specifies the element_group, see `element_group`.

See also `group_contact_spring_stiffness` and `group_contact_spring_friction_automatic`.

7.553 `group_contact_spring_plasti_friction_automatic` *index switch*

If *switch* is set to **-yes**, the friction coefficient for contact springs will be determined from the plasticity law angle of neighboring elements. For a neighboring `group_materi_plasti_mohr_coul` the friction coefficient f will be set to $f = (2./3.)\tan\phi$ with ϕ the friction angle in the mohr-coulomb law of the neighboring elements. For a neighboring `group_materi_plasti_diprisco` the friction coefficient f will be set to a value depending on the parameter γ of that law.

If no neighbor elements with appropriate material law are found, then f will be set to 0.2.

The *index* specifies the element_group, see `element_group`. See also `group_contact_spring_direction_automatic`.

7.554 `group_contact_spring_direction_automatic_planes` *index switch_x switch_y switch_z*

With this option you can help the `group_contact_spring_friction_automatic` by telling in which planes the automatically determined spring direction is allowed to be. If a switch is set to **-yes**, then the direction may have a component in that plane. If a switch is set to **-no**, then the direction may not have a component in that plane. Default all switches are **-yes**.

The *index* specifies the element_group, see `element_group`.

7.555 `group_contact_spring_memory` *index memory_type*

Memory model for contact_spring; either **-updated_linear**, **-total_linear**. The *index* specifies the element_group, see `element_group`.

7.556 `group_contact_spring_stiffness` *index k_N k_T*

Stiffnesses for contact springs. The force F_N in normal direction of the contact spring is determined from $F_N = k_N u_N$ where u_N is the normal displacement difference of the two nodes (that is, the displacement of the second node in normal direction minus the displacement of the first node in normal direction). The first tangential force F_{T1} of the contact spring is determined from $F_{T1} = k_T u_{T1}$ where u_{T1} is the tangential displacement difference of the two nodes in the first tangential direction; the same is done for the second tangential force. The total tangential force $\sqrt{F_{T1}^2 + F_{T2}^2}$ cannot exceed $f F_N$ with f friction coefficient; then frictional slip occurs and the total tangential force is set to $f F_N$. To model continuing stick between two bodies just put the friction coefficient f very high.

In 1D the parameters k_T and f will not be used (but should be specified as dummies nevertheless).

The *index* specifies the element_group, see `element_group`.

See also **group_contact_spring_friction** and **group_contact_spring_friction_automatic**.

7.557 group_dof_initial *index dof_0 dof_1 . . .*

Same as **element_dof_initial**, now specified for a group of elements however.

7.558 group_dof_initial_specific_number *index dof*

Same as **element_dof_initial_specific_number**, now specified for a group of elements however.

7.559 group_dof_initial_specific_value *index value_0 value_grad_x value_grad_y
value_grad_z*

Same as **element_dof_initial_specific_value**, now specified for a group of elements however.

7.560 group_groundflow_capacity *index C*

Capacity in ground water flow equation. The *index* specifies the element_group, see **element_group**.

7.561 group_groundflow_consolidation_apply *index switch*

If *switch* is set to **-yes** consolidation will be applied for the elements of the group. If *switch* is set to **-no** consolidation will not be applied for the elements of the group. Default *switch* is **-no**.

7.562 group_groundflow_expansion *index α*

Thermal expansion coefficient for ground water, for a combined groundwater with temperature analysis. The *index* specifies the element_group, see **element_group**.

7.563 group_groundflow_nonsaturated_vangenuchten *index S_{residu} S_{sat} g_a g_l
 g_n*

Parameters for non-saturated van Genuchten ground water flow, see the theory section. The *index* specifies the element_group, see **element_group**.

Since the van-Genuchten law is highly nonlinear, convergence of the calculation can be difficult. Always check if the calculation converges by printing **post_node_rhside_ratio**. You can try including inertia to improve convergence. Alternatively for calculations without inertia you can specify a relaxation factor with **control_relaxation** (try a factor of 0.1 or so).

7.564 group_groundflow_permeability *index pe_x pe_y pe_z*

Permeability coefficient in ground water flow, in each space direction. In 1D you only should specify pe_x , etc. If you specify only value, then that will be used in each direction. The *index* specifies the element_group, see **element_group**.

7.565 **group_groundflow_total_pressure_tension** *index plastic_tension_minimum water_height*

Using this option you can control that the water pressure in an element is at least the value as determined from the specified *water_height*. More precise, if the static water pore pressure as determined from the water density, the gravity and the *water_height* exceeds the pore water pressure from the groundflow equation (in absolute terms) , this static water pressure actually is used. This is only done if the largest eigenvalue of **materi_strain_plastic_tension** exceeds *plastic_tension_minimum*. To calculate the eigenvalues of **materi_strain_plastic_tension** you need to include **post_calcul -materi_strain_plasti_tension -prival** in the input file.

This option comes handy to take care that in cracks in concrete actually the largest water pressure from an environment is used. It so ensures that a critical safety analysis for concrete cracking is obtained.

7.566 **group_hinge_memory** *index memory_type*

Memory model for hinge elements; either **-updated_linear** or **-total_linear**. The *index* specifies the element_group, see **element_group**.

7.567 **group_hinge_elasti_penalty** *index penalty*

The rotational hinge stiffness should be specified with the **group_hinge_elasti_stiffness** record. For all deformations different from the hinge rotation, the hinge element uses a large penalty stiffness (to prevent such deformations). With this **group_hinge_elasti_penalty** factor you can specify the *penalty* factor for this penalty stiffness. Default, if **group_hinge_elasti_penalty** is not specified, a value of 1000. is used for *penalty*.

7.568 **group_hinge_elasti_stiffness** *index c_φ*

background Typically hinges are used in a tunnel composed by rings, with ring segments joined by hinges. Hinges are used to model a 'tuebingen concrete hinge' between two adjacent quadratic elements which are part of a 'tuebingen tunnel ring'.

hinge elements types Hinge elements in 2D are available by specifying **-quad4** or **-quad6** for *element*, and in 3D by specifying **-hex8** or **-hex18** for *element*,

hinge node sequence You need to specify in **element** the nodes of the hinge first for the first side of the hinge (for the first tunnel ring segment), and then the nodes for the second side of the hinge (so for the second tunnel ring segment). The nodes on each side should be specified in the typical Tochnog fashion (so just like for the regular isoparametric elements).

hinge node sequence The hinge 'length direction' is the direction along the hinge rotating surface. For example, in 3D the hinge direction is the hinge radial direction in a cross-section of the tunnel. In 3D you need to take special care with the node numbering in **element**, since it determines the hinge length direction. For example, consider a **-hex8** hinge element in 3D which is specified like this: **element 100 1 2 3 4 5 6 7 8**. Then nodes 1,2,3,4 are located on the first side, and nodes 5,6,7,8 are located on the second side. Moreover, the direction from node 1 to node 2 is the hinge length direction; the same hold for node sets 3,4 and 5,6 and 7,8.

hinge element geometry Both 2D and 3D hinge elements should be rectangular shaped (right angles between the edges) and non-distorted (middle nodes for quadratic elements exactly in the middle of the edges).

hinge elastic rotational stiffness With this **group_hinge_elasti_stiffness** record, you specify the elastic rotation stiffness c_ϕ for hinge elements. This is used in the elastic moment-rotation relationship for the hinge element: $M = c_\phi \phi$ where M is the moment in the hinge and ϕ is the rotation angle in the hinge. The *index* specifies the element_group, see **element_group**.

7.569 **group_hinge_plasti_moment** *index* $N_0 f_0 N_1 f_1 \dots$

Table for the factor f which is used to determine the maximum allowed moment in hinge elements. The table specifies pairs of normal force and corresponding factors. Given a normal force in the hinge, the relevant factor f is determined. A typical table follows from the leonhard/reinmann curve for tuebingen tunnel ring hinges.

Using the determined factor f , the maximum moment follows from the relation $M_{max} = f N$ with N the normal force in the hinge.

As a special option, you can specify one and only one value for f **group_hinge_plasti_moment**. Then this value f has a fixed value, and does not depend on the normal force. Again, the maximum moment is calculated from $M_{max} = f N$. A typical value for fixed valued f is $0.28l$ with l being the effective hinge length.

7.570 **group_integration_method** *index method*

Here *method* sets the integration method for bars, quad en hex elements. You can either set *method* to **-gauss** or **-lobatto**.

If this record is not set, the default method as described in **group_integration_points** is chosen.

It is advised to keep the default method, so not specify this **group_integration_method** record, unless you know what you are doing.

7.571 **group_integration_points** *index type*

Here *type* sets the number of integration points in an element. It should be set to **-normal**, **-minimal** or to **-maximal**.

For **-tria3** elements the integration point will be located in the middle with **-minimal** integration, or a four-point integration scheme will be used with **-maximal** integration.

For **-tria6** elements a seven-point scheme will be used for **-maximal** and a four-point scheme will be used with **-minimal** integration.

For **-tet4** elements the integration point will be located in the middle with **-minimal** integration, or a five-point integration scheme will be used with **-maximal** integration.

For **-tet10** elements a five-point scheme will be used for **-minimal** and a ten-point scheme will be used with **-maximal** integration.

For other elements, if **-minimal** is used then the number of integration points in a direction is set equal to the number of nodes in the direction minus 1, and gauss integration is used. If for the

other elements **-maximal** is used then the number of integration points in a direction is set equal to the number of nodes in the direction; gauss integration is used, but in case inertia is applied then lobatto integration will be used.

Default **-minimal** is used for **-bar2**, **-tria3**, and **-tet4** elements; it is default **-maximal** otherwise.

If *type* is set to **-normal**, the default integration will be used.

The above is valid for normal isoparametric elements. For interface elements default lobatto integration is used (integration points in nodes).

It is advised to keep the default method, so not specify this **group_integration_points** record.

The *index* specifies the element_group, see **element_group**.

7.572 **group_interface_index** *switch*

With this record, you set that the element with element group *index* will act as an interface element by setting *switch* to **-yes**. This is available for **-quad4**, **-quad6**, **-hex8**, **-hex18**, **-prism6** and **-prism12**.

See **group_interface_*** which data can be set for interfaces.

In interfaces strains are displacement differences between the opposite interface sides.

7.573 **group_interface_condif_conductivity** *index k*

The 'index' specifies the group number. The conductivity *k* specifies the heat flow in interface thickness direction per unit temperature difference. Thus the conductivity is not the material conductivity but the conductivity of the layer simulated by the interface incorporating the thermal thickness of the interface, The 'conductivity' has units [power]/[temperature*length] in 2D, and [power]/[temperature*length*length] in 3D.

7.574 **group_interface_gap** *index gap*

By specifying this record you can account for initial empty space between the sides of an interface element. Only when the sides displacements are such that this initial gap is closed, then the interface element will start to generate stresses. This is accomplished in the program by setting the stiffness of the interface element to zero or a very small value as long as the gap is not closed.

As a special case, setting *gap* to 0 means that the gap option is inactive and will not be used.

7.575 **group_interface_groundflow_capacity** *index C*

This record specifies the capacity for interface elements.

7.576 **group_interface_groundflow_permeability** *index pe*

This record specifies the permeability per unit length in 2D or unit area in 3D for interface elements.

7.577 `group_interface_materi_elasti_stiffness` *index kn kt,first kt,second*

This record allows you to specify a normal stiffness and tangential shear stiffnesses for discrete interface elements with **-materi** in **group_type**. Normal stresses in the interface element follow from normal strains multiplied with *kn* ($\text{stress,normal} = \text{kn} * \text{strain,normal}$). Shear stresses in the interface element in the first tangential direction follow from shear strains in the first tangential direction multiplied with *kt,first* ($\text{stress,shear,first} = \text{kt,first} * \text{shear,gamma,first} = 2 * \text{kt,first} * \text{strain,shear,first}$). Shear stresses in the interface element in the second tangential direction follow from shear strains in the second tangential direction multiplied with *kt,second* ($\text{stress,shear,second} = \text{kt,second} * \text{shear,gamma,second} = 2 * \text{kt,second} * \text{strain,shear,second}$). The *kt,second* should be specified for 3D interfaces only.

Too high values for interface stiffness will cause convergence problems in calculations. Thus, if you are running a calculation with interface elements and you are experiencing convergence problems please try lower values for the interface stiffnesses. Typically the normal interface stiffness can be chosen as 10 times the Young's modulus of the neighbouring isoparametric element divided by the length of that element in normal direction. Typically the tangential interface stiffness can be chosen as half of the normal interface stiffness.

A 3d example:

```
...
number_of_space_dimensions 3
...
group_interface_materi_elasti_stiffness 0 0.10000e+11 0.50000e+10 0.50000e+10
...
```

7.578 `group_interface_materi_elasti_stiffness_normal_diagram` *index strain,normal,0 strain,normal,1 ... kn,0 kn,1 ...*

Same as **group_interface_materi_elasti_stiffness_tangential_diagram**, but now for the normal stiffness however. The normal stiffness depends on the value of the normal strain.

In the data record first the normal strains should be given (specify both negative and positive normal strains). Then the normal stiffnesses should be given corresponding with the specified shear strains.

7.579 `group_interface_materi_elasti_stiffness_tangential_diagram` *index strain,shear,0 strain,shear,1 ... kt,first,0 kt,first,1 ... kt,second,0 kt,second,1 ...*

With this data record you can make the tangential stiffnesses dependent on the tangential strains.

The first tangential stiffness depends on the absolute value of the first shear strain. The second tangential stiffness depends on the absolute value of the second shear strain.

In the data record first the shear strains should be given (specify only non-negative shear strains). Then the tangential stiffnesses should be given corresponding with the specified shear strains.

Notice that both shear stiffnesses are specified for the same shear strain values; however, the first shear stiffness indeed does depend on the first shear strain and the second shear stiffness indeed does depend on the second shear strain.

You also need to specify the **group_interface_materi_elasti_stiffness** for the normal stiffness.

The tangential stiffness from **group_interface_materi_elasti_stiffness** will be overwritten with the values specified in **group_interface_materi_elasti_stiffness_tangential_diagram**.

See **group_interface_tangential_reference_point** how you can influence the tangential direction in the interface element.

7.580 **group_interface_materi_expansion_normal** *index expansion_coefficient_normal*

The 'index' specifies the group number. The *expansion_coefficient_normal* specifies the thermal strain expansion in interface thickness direction per unit temperature in the interface. The temperature is the average of the temperature of the both sides at the location of the integration point. This option is only available if **group_interface_materi_memory** is set to **-total_linear** or **-updated_linear**. Furthermore, **materi_strain_elasti** should be initialised.

7.581 **group_interface_materi_hardening** *index factor*

To prevent excessive penetration of materials separated by an interface element, you can specify with *factor* by how much the normal stiffness of the interface element will be increased at increasing compressive normal strain in the interface element. So, the stiffness then reads: $kn = kn(0) + (\text{factor} - kn(0))\epsilon$, where ϵ is the absolute value of the compressive normal strain, and $kn(0)$ is the normal stiffness at zero compressive normal strain.

This **group_interface_hardening** record will be applied to the normal stiffness given in **group_interface_mat**

7.582 **group_interface_materi_memory** *index memory_type*

Either *memory_type* should be set to **-updated_linear** or **-total_linear**.

7.583 **group_interface_materi_plasti_mohr_coul_direct** *index phi c phiflow*

Mohr-coulomb plasticity model for interfaces. The angles are in radians. The cohesion c has stress unit (so just the same as for **group_materi_plasti_mohr_coul** in normal isoparametric elements). The maximum friction force in the interface is $c + F_n * \tan(\phi)$ where c is the cohesion, ϕ is the friction angle in radians and F_n is the normal force (which is a negative value under compression).

7.584 **group_interface_materi_plasti_tension_direct** *index switch*

If *switch* is set to **-no** then the stresses are set to 0 if the interface normal strain is positive.

This **group_interface_materi_plasti_tension_direct** is not allowed in combination with **group_interface_ga**

Default, if **group_interface_materi_tension_direct** is not specified, *switch* is set to **-yes**.

7.585 **group_interface_materi_residual_stiffness** *index factor*

The calculations are more stable if some residual stiffness is added to an opened interface. With *factor* you can set the part of the original stiffness to be used as stiffness in opened interfaces.

For maximum stability use 1 for the factor, but then also use a high number of timesteps to allow for convergence to the correct solution.

Default, if this **group_interface_materi_residual_stiffness** is not specified, then *factor* is set to 1.e-2.

7.586 group_interface_materi_stress_displacement_normal_diagram *index displacement_0 stress_0 displacement_1 stress_1 ...*

This record specifies a diagram for normal interface stresses as function of the normal interface displacement difference between the opposite interface sides. This record should be used in combination with **group_interface_materi_stress_displacement_tangential_diagram**. This record cannot be used in combination with other **group_interface_materi...** records.

7.587 group_interface_materi_stress_displacement_tangential_diagram *index displacement_0,first stress_0,first displacement_1,first stress_1,first ... displacement_0,second displacement_1,second stress_1,second ...*

This record specifies a diagram for tangential (shear) interface stresses as function of the tangential interface displacement difference between the opposite interface sides. The first diagram holds for the first tangential direction. The second diagram holds for the second tangential direction (only in 3D). If both the first and second diagram are specified (in 3D), these diagrams should have an equal length. This record should be used in combination with **group_interface_materi_stress_displacement_normal_diagram**.

In case the normal stress in the interface is not negative, the interface is considered to be opened and the shear stress will be lowered by the factor **group_interface_materi_residual_stiffness**. This record cannot be used in combination with other **group_interface_materi...** records.

7.588 group_interface_materi_stress_displacement_user *index switch*

If you set *switch* to **-yes** the user supplied routine for interface stresses as function of displacements will be called. You can set parameters for the routine via **group_interface_materi_stress_displacement_user_parameters**.

In case the normal stress in the interface is not negative, the interface is considered to be opened and the shear stress will be lowered by the factor **group_interface_materi_residual_stiffness**.

7.589 group_interface_materi_stress_displacement_user_parameters *index switch*

See **group_interface_materi_stress_displacement_tangential_diagram**.

7.590 group_interface_groundflow_total_pressure_tension *index strain_normal_minimum water_height*

Using this option you can control that the water pressure in an interface element is at least the value as determined from the specified *water_height*. More precise, if the static water pore pressure as determined from the water density, the gravity and the *water_height* exceeds the pore water pressure from the groundflow equation (in absolute terms) , this static water pressure actually is

used. This is only done if the interface normal strain (displacement difference between interface sides) exceeds *strain_normal_minimum*.

This option comes handy to take care that in cracks in concrete actually the largest water pressure from an environment is used. It so ensures that a critical safety analysis for concrete cracking is obtained.

7.591 **group_interface_tangential_reference_point** *index point_x point_y point_z*

This data record defines a reference point that allows you to influence the tangential directions in a 3D interface element. The tangential directions will be setup as follows:

- The normal direction to the interface plane is determined.
- A vector is taken from the integration point in the interface element to the reference point.
- The part of this vector perpendicular to the normal direction defines the first tangential direction.
- The outer product of the normal direction and the first tangential direction gives the second tangential direction.

The above procedure ensures that the tangential directions are perpendicular to the normal direction, and that the first tangential directions points as much as possible to the reference point. As a typical example, you can use this option to take care that the first tangential direction points to the middle of a tunnel, so the first tangential interface direction equals in fact the tunnel radial direction; to do so specify the middle point on the tunnel axis as reference point *point_x point_y point_z*.

If this **group_interface_tangential_reference_point** is not specified, it is only certain that the tangential directions are in plane of the interface (perpendicular to the normal direction), but are not defined otherwise.

See also **element_interface_intpnt_direction**.

7.592 **group_materi_damage_mazars** *index epsilon₀ a_t b_t a_c b_c β*

Parameters for the Mazars damage law. The *index* specifies the element_group, see **element_group**.

7.593 **group_materi_damping** *index d*

Material damping coefficient d_1 or d_2 . See **group_materi_damping_method**. if *method* is set to **-method1** then d_1 is used. if *method* is set to **-method2** then d_2 is used.

The *index* specifies the element_group, see **element_group**.

7.594 **group_materi_damping_method** *index method*

See **group_materi_damping**.

7.595 `group_materi_density` *index density*

Density for material flow equation. The *index* specifies the `element_group`, see **element_group**.

7.596 `group_materi_density_groundflow` *index density_wet density_dry*

Density for material flow equation when a calculation is performed in combination with groundflow. If the element is filled with groundwater the *density_wet* will be used and otherwise the *density_dry* will be used. To determine if an element is filled with water, tochnog does the following: If **post_calcul -groundflow_pressure -total_pressure** is put in the input file then total pressures (pore pressures) are calculated. Then if the pore pressure in an element is negative the wet density is taken. Otherwise the dry density. If **post_calcul -groundflow_pressure -total_pressure** is NOT put in the input file the total pressures are not calculated. Then tochnog looks if a phreatic level is given; if so, then if an element is below the phreatic level the wet density is used, otherwise if an element is above the phreatic level the dry density is used.

Here *density_wet* is the amount of kg of soil + water in a unit volume. And *density_dry* is the amount of kg of soil in a unit volume.

The *index* specifies the `element_group`, see **element_group**.

In case total pressures are calculated

In case total pressures are calculated from the **post_calcul groundflow_pressure -total_pressure** command, the *density_wet* will be used if the total pressure is smaller than 0, whereas *density_dry* will be used if the total pressure is larger or equal to 0.

In case total pressures are not calculated but a phreatic level is specified

In case an element is above a specified phreatic level the *density_dry* will be used. In case an element is below a specified phreatic level, the *density_wet* will be used.

In other cases

In other cases *density_dry* will be used.

7.597 `group_materi_elasti_borja_tamagnini` *index $G_0 \propto \hat{k} p_r$*

Elastic data for the modified Borja Tamagnini model, see [1]. The *index* specifies the `element_group`, see **element_group**.

7.598 `group_materi_elasti_camclay_g` *index G*

Elastic data G for the modified CamClay model. The *index* specifies the `element_group`, see **element_group**.

7.599 `group_materi_elasti_camclay_gmin` *index $gmin$*

This specifies a minimal allowed value for G in the modified CamClay model, to prevent numerical problems for very low G values.

The *index* specifies the `element_group`, see **element_group**.

7.600 **group_materi_elasti_camclay_poisson** *index* ν

Elastic data ν for the modified CamClay model. This option is alternative to the **group_materi_elasti_camclay** option (so, only one of both can be defined). With this option the poisson ratio ν is assumed constant, and is used as follows:

$$G = \frac{3}{2}K(1 - 2\nu)/(1 + \nu)$$

The *index* specifies the element_group, see **element_group**.

7.601 **group_materi_elasti_compressibility** *index* co

Compressibility for materials. A positive value should be used. The *index* specifies the element_group, see **element_group**.

7.602 **group_materi_elasti_hardsoil** *index* E_{50}^{ref} σ_{50}^{ref} ν_{50} m E_{ur}^{ref} σ_{ur}^{ref} ν_{ur}

Elasticity data for Hardening Soil model. The *index* specifies the element_group, see **element_group**.

7.603 **group_materi_elasti_k0** *index* $K0$

Elastic data $K0$. When this data is specified, and also **control_materi_elasti_k0** is set to **-yes**, then the $K0$ parameter will be used in the elastic stress law with **group_materi_elasti_young** or **group_materi_elasti_young_power** and **group_materi_elasti_poisson**, or with **group_materi_elasti_hardsoil**. In fact it will be used to determine the poisson coefficient consistent with the $K0$; this poisson coefficient is used in the elastic stress law.

This **group_materi_elasti_k0** in combination with **control_materi_elasti_k0** is a convenient method to get 'K0 stresses' when imposing gravity in a geotechnics calculation. After gravity is imposed simply do not set the **control_materi_elasti_k0** anymore, so that the normal **group_materi_elasti_poisson** will be used in the remaining steps.

For $K0 \leq 0.95$ Tochnog will take 0.95. $K0$ exceeding 1 (or 0.95) may lead to ill-conditioned calculations.

7.604 **group_materi_elasti_lade** *index* B R λ

Elastic data $B = 0$, R , λ for the Lade model. The *index* specifies the element_group, see **element_group**.

7.605 **group_materi_elasti_poisson** *index* $poisson$

Poisson ratio for solid. The *index* specifies the element_group, see **element_group**.

7.606 **group_materi_elasti_shear_factor** *index* $factor$

Specifying this record causes the shear stiffness following from a specified young and poisson to be multiplied with *factor*. This provides a convenient way to test in a calculation what the effect of low shear stresses is. The *index* specifies the element_group, see **element_group**.

7.607 **group_materi_elasti_stress_pressure_history_factor** *index factor*

This record allows you to model a different soil stiffness when first loading or unloading/reloading instead. The **materi_stress_pressure_history** should be initialised, which records the maximum soil pressure that occurred in history. If the current pressure is smaller then the largest pressure in history, the material is unloading or reloading, and the stiffness will be multiplied with *factor*. If the current pressure is the larger then the largest pressure from history, then this current pressure becomes the maximum history pressure, and the stiffness will not be multiplied with *factor*. The *factor* typically may be $\frac{1}{3}$.

This **group_materi_elasti_stress_pressure_history_factor** can be combined with the young as specified by **group_materi_elasti_young** or the young calculated from **group_materi_elasti_young_power**.

7.608 **group_materi_elasti_transverse_isotropy** *index E₁ E₂ ν_1 ν_2 G₂ dir_x dir_y dir_z*

Specifies the unique direction (*dir_x dir_y dir_z*) and elastic moduli in the transverse isotropic model. The *index* specifies the element_group, see **element_group**.

7.609 **group_materi_elasti_volumetric_poisson** *index ν*

See **group_materi_elasti_volumetric_young_values**

7.610 **group_materi_elasti_volumetric_young_order** *index n*

See **group_materi_elasti_volumetric_young_values**

7.611 **group_materi_elasti_volumetric_young_values** *index epsilon_0 sigma_0 epsilon_1*

This is a special record to model the volumetric stress part of a nonlinear material, given the experimental results of a volumetric compression test (compression in one direction, fixed size in other two directions).

The table *epsilon_0 sigma_0 epsilon_1 sigma₁ ...* specifies the strain-stress results for the volumetric compression test. Together with the poisson ratio as specified in **group_materi_elasti_volumetric_poisson** an isotropic law in a nonlinear Young's modulus and a constant poisson ratio is fitted to this experiment. The Young modulus in fact is taken as the polynomial expansion $E_0 + E_1\epsilon + E_2\epsilon^2 + \dots + E_{n-1}\epsilon^{n-1}$ where n denotes the order of the polynomial expansion (as given in **group_materi_elasti_volumetric_young_order**).

The poisson ratio should be taken very high, say 0.4999999 or so, to ensure that the resulting law only models volumetric stresses. Then afterwards a normal young-poisson isotropic law (**group_materi_elasti_young** and **group_materi_elasti_poisson**) can be added to get an extra deviatoric part.

7.612 **group_materi_elasti_young** *index E*

Young's modulus for solid material. The *index* specifies the element_group, see **element_group**.

7.613 **group_materi_elasti_young_polynomial** *index* $E_0 E_1 \dots$

Polynomial parameters for strain dependent Young's modulus for solid material. See the theory part. The *index* specifies the element_group, see **element_group**.

7.614 **group_materi_elasti_young_power** *index* $p_0 E_0 \alpha$

Power law Young's modulus for solid material. See the theory part. For small $p < \epsilon * p_0$ (where ϵ is a small value), tochnog takes $p = \epsilon p_0$ to prevent numerical difficulties for small stresses. The *index* specifies the element_group, see **element_group**.

If you want to get the calculated young as output, initialise with **materi_history_variable 1**; the history variable will be filled with the calculated young, and can be plotted by example in GID. See also **group_materi_elasti_young_power_eps**.

7.615 **group_materi_elasti_young_power_eps** *index* ϵp_0

To prevent problems with small young at low stresses for **group_materi_elasti_young_power**, you can demand that pressure levels below ϵp_0 will not be used in the power law, but instead ϵp_0 will actually be used at lower pressures. Default ϵp_0 is set to 1.e-2.

7.616 **group_materi_elasti_young_user** *index* *switch*

If *switch* is set to **-yes** the user supplied routine **user_young** will be called. There the youngs modulus should be calculated from the solution fields and the stress history. Typically degradation of material stiffness for cyclic loading can be programmed with this user specified routine.

You can plot in gid the values for the young as follows:

```
...
print_group_data -group_materi_elasti_young
...
```

7.617 **group_materi_expansion_linear** *index* α

Linear expansion coefficient. The *index* specifies the element_group, see **element_group**.

7.618 **group_materi_expansion_volume** *index* β

Volume expansion coefficient. The *index* specifies the element_group, see **element_group**.

7.619 **group_materi_factor** *index* *factor*

This factor comes convenient if your material stress law is specified in other units then you actually want in your calculation. Then you can specify *factor* to take care that your material stresses

become consistent with the remaining part of the input file. By example, if you want your input file to work with kPa but your material stress law works with MPa then simply set *factor* to 1000.

7.620 `group_materi_failure_crunching` *index threshold delete_time*

If the compression strain in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

7.621 `group_materi_failure_damage` *index threshold delete_time*

If the damage in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

7.622 `group_materi_failure_plasti_kappa` *index threshold delete_time*

If the plastic parameter kappa in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

7.623 `group_materi_failure_rupture` *index threshold delete_time*

If the tensile strain in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

7.624 `group_materi_failure_void_fraction` *index threshold delete_time*

If the void fraction in an element exceeds *threshold*, the element is considered to be fail. The element will be slowly deleted. It is totally deleted if the *delete_time* has passed.

The *index* specifies the element_group, see **element_group**.

7.625 `group_materi_history_variable_user` *index switch*

Set *switch* to **-yes** if you want to activate the user supplied routine for material history variables. The *index* specifies the element_group, see **element_group**.

7.626 `group_materi_history_variable_user_parameters` *index ...*

Specify parameters for the user supplied routine for material history variables. The *index* specifies the element_group, see **element_group**.

7.627 `group_materi_hyper_besseling` *index* $K_1 K_2 \alpha$

Parameters for Besseling Hyper elastic rubber model. The *index* specifies the `element_group`, see `element_group`.

7.628 `group_materi_hyper_blatz_ko` *index* $G\beta$

Parameters for Blatz-Ko model. The *index* specifies the `element_group`, see `element_group`.

7.629 `group_materi_hyper_mooney_rivlin` *index* $K_1 K_2$

Parameters for Mooney-rivlin hyper elastic rubber model. The *index* specifies the `element_group`, see `element_group`.

7.630 `group_materi_hyper_neohookean` *index* K_1

Parameter for Neo-Hookean hyper elastic rubber model. The *index* specifies the `element_group`, see `element_group`.

7.631 `group_materi_hyper_reduced_polynomial` *index* $K_1 K_2 \dots$

Parameters for reduced polynomial hyper elastic rubber model. The *index* specifies the `element_group`, see `element_group`.

7.632 `group_materi_hyper_volumetric_linear` *index* K

Parameter for the linear volumetric hyperelasticity model. The *index* specifies the `element_group`, see `element_group`.

7.633 `group_materi_hyper_volumetric_murnaghan` *index* $K\beta$

Parameter for the murnaghan volumetric hyperelasticity model. The *index* specifies the `element_group`, see `element_group`.

7.634 `group_materi_hyper_volumetric_ogden` *index* $K\beta$

Parameter for the ogden volumetric hyperelasticity model. The *index* specifies the `element_group`, see `element_group`.

7.635 `group_materi_hyper_volumetric_polynomial` *index* $K_0 K_1 \dots$

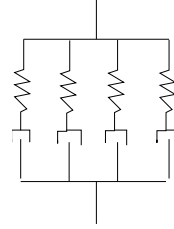
Parameters for the polynomial volumetric hyperelasticity model. The *index* specifies the `element_group`, see `element_group`.

7.636 `group_materi_hyper_volumetric_simo_taylor` *index K*

Parameter for the simo-taylor volumetric hyperelasticity model. The *index* specifies the element_group, see **element_group**.

7.637 `group_materi_maxwell_chain` *index E_0 t_0 ... E_{n-1} t_{n-1}*

In total n parallel maxwell chains are defined with stiffness E_0 , relaxation time t_0 , etc..



The number n should equal **materi_maxwell_stress** in the input initialization part. The *index* specifies the element_group, see **element_group**.

7.638 `group_materi_membrane` *index switch*

If **switch** is set to **-yes** the zz stress becomes zero in 2D and the yy and zz stress become zero in 1D (in combination with axi-symmetry in 1D, only the yy stress becomes zero since zz is the axi-symmetric direction). If **group_materi_membrane** is not used the plane strain conditions are used. Always the z -thickness is 1. in 3D, and the y , and z -thickness are 1. in 2D; see however also **volume_factor**.

The **group_materi_membrane** option cannot be used in combination with **group_materi_elasti_compression**, **group_materi_hyperelasticity** and **group_materi_viscosity**.

The *index* specifies the element_group, see **element_group**.

7.639 `group_materi_memory` *index memory_type*

Either *memory_type* should be set to **-updated**, **-updated_jaumann**, **-updated_linear**, **-total** or **-total_linear**. See the theoretical part for some explanation.

For an linear total Lagrange solid the input file may look like, and is recommended for most solid calculations:

```
...
materi_velocity
materi_displacement
materi_strain_total
materi_stress
end_initia
...
node 1 ...
node 2 ...
...
```

```

group_materi_memory 0 -total_linear
group_materi_elasti_young 0 ...
...
end_data

```

For a large deformation total Lagrange solid with a straightforward decomposition of the deformation tensor into a rotation tensor and a stretch tensor the input file may look like

```

...
materi_velocity
materi_displacement
materi_strain_total
materi_stress
end_initia
...
group_materi_memory 0 -total
group_materi_elasti_young 0 ...
...
end_data

```

For an updated Lagrange solid the input file may look like

```

...
materi_velocity
materi_velocity_integrated
materi_stress
end_initia
...
mesh -follow_material ...
...
node 1 ...
node 2 ...
...
group_materi_memory 0 -updated
group_materi_elasti_young 0 ...
...
end_data

```

Notice that for an updated Lagrange formulation you should always set that the mesh follows the material.

For a fluid the input file may look like

```

...
materi_velocity
materi_stress
end_initia
...
(use Eulerian mesh)
mesh -fixed_in_space ...
timestep_predict_velocity -yes

```

```

...
node 1 ...
node 2 ...
...
group_materi_memory 0 -updated_linear
group_materi_viscosity 0 ...
group_materi_elasti_compressibility 0 ...
...
end_data

```

The *index* specifies the element_group, see **element_group**.

7.640 **group_materi_plasti_bounda** *index index_0 index_1 ...*

With this option, you can model reduction of friction of soil material and alike granular materials on walls. Set *index_0*, *index_1* etc. to the index of the **bounda_dof** records for which you want to use this reduction. We define an element to be on a wall when at least one of the velocities (displacements) of the elements is prescribed (via **bounda_dof**). As a special option, you can use **-all** which indicates that the **bounda_dof** records for all indeces will be used.

The reduction of friction is done for **group_materi_plasti_mohr_coul**, **group_materi_plasti_matsuoka_nak**, **group_materi_plasti_druck_prag**, **group_materi_plasti_hardsoil**, if specified, by reducing the friction angle *phi* and dilatancy angle *phi_flow* and cohesion *c* of the granular material with a factor (2./3.).

This is done for **group_materi_plasti_camclay**, if specified, by reducing *M* with a factor (2./3.).

This is done for **group_materi_plasti_hypo_***, if specified, by reducing deviatoric stress increments with a factor (2./3.).

The *index* specifies the element_group of the granular material, see **element_group**.

See also **group_materi_plasti_bounda_factor**.

7.641 **group_materi_plasti_bounda_factor** *index factor*

With this record you can specify a factor other than the default 2./3. used by the **group_materi_plasti_bounda** record. You need to specify a factor for each of *index_0*, *index_1* etc.

The *index* specifies the element_group of the granular material, see **element_group**.

7.642 **group_materi_plasti_camclay** *index M κ λ*

Plastic data *M*, *κ* and *λ* for the modified CamClay model. The *index* specifies the element_group, see **element_group**.

7.643 **group_materi_plasti_cap1** *index φ c M λ* κ* K^{ref} p^{ref} m*

Plastic data for the cap1 plasticity model.

The *index* specifies the element_group, see **element_group**.

7.644 group_materi_plasti_cap2 *index c ϕ α R ϵ_p^p p_b ...*

Plastic data for the cap2 plasticity model. The ϵ_p^p p_b ... represents a table with ϵ_p^p versus p_b values; at least two sets of values need to be specified.

The *index* specifies the element_group, see **element_group**.

7.645 group_materi_plasti_compression *index sigy*

Yield data for compression plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

7.646 group_materi_plasti_compression_direct *index sigy*

Compression limit. Principal stresses lower than *sigy* are not allowed and will be cut off by Tochnog. This model uses directly a cut-off of stresses, and does not use plastic strains. The *index* specifies the element_group, see **element_group**.

You can apply softening with a **dependency_diagram** on **materi_strain_total_compression_kappa**.

7.647 group_materi_plasti_diprisco *index γ $\hat{\beta}_f$ b_p c_p t_p $\hat{\theta}_c$ $\hat{\theta}_e$ ξ_c ξ_e β_f^0*

Yield data for di Prisco plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** and **materi_plasti_diprisco_history 11** should be initialized.

7.648 group_materi_plasti_diprisco_density *index γ_l $\hat{\beta}_{lf}$ b_{lp} c_{lp} t_{lp} $\hat{\theta}_{lc}$ $\hat{\theta}_{le}$ ξ_{lc} ξ_{le} β_{lf}^0 γ_d $\hat{\beta}_{df}$ b_{dp} c_{dp} t_{dp} $\hat{\theta}_{dc}$ $\hat{\theta}_{de}$ ξ_{dc} ξ_{de} β_{df}^0 e_l e_d*

Yield data for di Prisco plasticity with varying density. All data with an *l* in the subscript holds for loose soil, whereas all data with an *d* in the subscript holds for dense soil. The actually used data will be interpolated between the loose and dense data using the current density.

The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** and **materi_plasti_diprisco_history 12** should be initialized.

7.649 group_materi_plasti_druck_prag *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Drucker-Prager plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

7.650 group_materi_plasti_element_group *index group_0 group_1 ...*

With this record you can model frictional slip of soil material and alike granular materials on other materials like concrete, steel, etc.

This is done for **group_materi_plasti_mohr_coul**, **group_materi_plasti_matsuoka_nakai**, **group_materi_plasti_druck_prag**, **group_materi_plasti_hardsoil**, if specified,

by reducing the friction angle ϕ and dilatancy angle ϕ_{flow} and cohesion c of the granular material with a factor (2./3.).

This is done for **group_materi_plasti_camclay**, if specified, by reducing M with a factor (2./3.).

This is done for **group_materi_plasti_tension**, if specified, by reducing σ_y with a factor (2./3.).

This is done for **group_materi_plasti_hypo_***, if specified, by reducing the deviatoric stress increments with a factor (2./3.).

With *group_0* , *group_1* etc. you can specify the groups of the concrete material, steel material etc. The reduction of the friction angle and dilatancy angle will only be applied to the granular elements (of *element_group*) which are a direct neighbor of an element which has one of the groups *group_0* , *group_1* etc.

Please realise that this method only works well if the finite elements are not too large.

The *index* specifies the element_group of the granular material, see **element_group**.

See also **group_materi_plasti_element_group_factor**.

7.651 **group_materi_plasti_element_group_factor** *index factor_0 factor_1 ...*

With this record you can specify a factor other then the default 2./3. used by the **group_materi_plasti_element_group_factor** record. You need to specify a factor for each group.

The *index* specifies the element_group of the granular material, see **element_group**.

7.652 **group_materi_plasti_generalised_non_associate_cam_clay_for_bonded_soils** *index ...*

Yield data for the Generalised Non Associate Cam Clay for Bonded Soils plasticity model. The *index* specifies the element_group, see **element_group**.

7.653 **group_materi_plasti_gurson** *index sigy q1 q2 q3*

Yield data (also used as flow data) for Gurson plasticity. The *index* specifies the element_group, see **element_group**.

7.654 **group_materi_plasti_hardsoil** *index ϕ c ψ R_f*

Plasticity data for Hardening Soil model. The *index* specifies the element_group, see **element_group**.

This model requires sufficient small timesteps; in case of trouble try smaller timesteps.

7.655 **group_materi_plasti_heat_generation** *factor*

This *factor* specifies how much of the plastic energy loss is transformed into heat (this only makes sense if **condif_temperature** is initialized). The *factor* should be between 0 and 1. The *index* specifies the element_group, see **element_group**.

7.656 `group_materi_plasti_hypo_cohesion` *index* c

Cohesion parameter in hypoplastic law; see the theory section. The *index* specifies the element_group, see **element_group**.

7.657 `group_materi_plasti_hypo_strain_intergranular` *index* $R\ m_R\ m_T\ \beta_x\ \chi\ \gamma$

Intergranular strain parameters in hypoplastic law; see the theory section. The *index* specifies the element_group, see **element_group**.

7.658 `group_materi_plasti_hypo_masin` *index* $\varphi_c\ \lambda^*\ \kappa^*\ N\ r$

Masin hypoplasticity parameters; see the theory section. The angle φ_c should be specified in degrees. The λ^* should be bigger than the κ^* .

7.659 `group_materi_plasti_hypo_masin_ocr` *index* OCR

OCR in masin hypoplastic law; the initial void ratio will be calculated from this. You need to set **control_materi_plasti_hypo_masin_ocr_apply** to -yes.

7.660 `group_materi_plasti_hypo_masin_structure` *index* $k\ A\ s_f$

Masin hypoplasticity structure parameters; see the theory section. The k should be at least 0. The A should be greater or equal to 0, and lower than 1. The s_f should be greater or equal to 1.

7.661 `group_materi_plasti_hypo_wolffersdorff` *index* $\varphi\ h_s\ n\ e_{c0}\ e_{d0}\ e_{i0}\ \alpha\ \beta$

Von-Wolffersdorff parameters in hypoplastic law; see the theory section. Here φ is in degrees. The *index* specifies the element_group, see **element_group**.

7.662 `group_materi_plasti_hypo_niemunis_visco` *index* $\varphi\ \nu\ D_r\ I_v\ e_{e0}\ p_{e0}\ \lambda\ \beta_R\ \kappa$

Parameters $\varphi\ \nu\ D_r\ I_v\ e_{e0}\ p_{e0}\ \lambda\ \beta_R\ \kappa$ for the visco part of hypoplasticity; see the theory section.

The history variables are the same as for **group_materi_plasti_hypo_wolffersdorff**. You also need to specify **control_materi_plasti_hypo_niemunis_visco_ocr_apply**.

The *index* specifies the element_group, see **element_group**.

7.663 `group_materi_plasti_hypo_niemunis_visco_ocr` *index* OCR

OCR in visco hypoplastic law. The initial void ratio will be calculated from this; see the theory section.

In case you would like to have an OCR dependent on space coordinate you can use **dependency_diagram** and **dependency_item**.

The *index* specifies the element_group, see **element_group**.

7.664 **group_materi_plasti_hypo_void_ratio_linear** *index switch*

Normally the changing void ratio in hypoplasticity is calculated exactly from the initial void ratio and the exact volume change of the material (using the determinant of the deformation tensor).

Optionally, if *switch* is set to **-yes**, this can be linearly approximated by using the trace of the deformation tensor; this can be convenient to compare results with analytical theories which are based on such linear approximation of void ratio changes.

7.665 **group_materi_plasti_kinematic_hardening** *index a*

This record specifies the size of the rate of the kinematic hardening matrix ρ_{ij} . The *index* specifies the element_group, see **element_group**.

7.666 **group_materi_plasti_laminate0_direction** *index dir_x dir_y dir_z*

Specifies 3 components of the vector normal to the plane of laminate 0. For other laminates you need to use **group_materi_plasti_laminate1_direction** etc.

The *index* specifies the element_group, see **element_group**.

7.667 **group_materi_plasti_laminate0_mohr_coul** *index phi c phiflow*

Parameters of laminate 0 for the Mohr-Coulomb plasticity model. Here *phi c phiflow normal_x normal_y normal_z* are the friction angle, cohesion and dilatancy angle. For other laminates you need to use **group_materi_plasti_laminate1_mohr_coul** etc.

The *index* specifies the element_group, see **element_group**.

7.668 **group_materi_plasti_laminate0_tension** *index sigma_t*

Tension cutoff stress for the tension plasticity model for laminate 0. For other laminates you need to use **group_materi_plasti_laminate1_tension** etc.

The *index* specifies the element_group, see **element_group**.

7.669 **group_materi_plasti_matsuoka_nakai** *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Matsuoka-Nakai plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. It is advised to use **group_materi_plasti_tension** or preferably with **group_materi_plasti_tension_direct** for tension cutoff of large tension stresses. The *index* specifies the element_group, see **element_group**.

7.670 `group_materi_plasti_matsuoka_nakai_hardening_softening` *index phi_0 c_0 phiflow_0 phi_1 c_1 phiflow_1 kappashear_crit*

Both yield data and flow data (indicated by the word flow) for Matsuoka-Nakai hardening-softening plasticity. See the theoretical part. Choose each of the angles *phi_0* *phiflow_0* *phi_1* *phiflow_1* in between 0 and $\frac{\pi}{2}$. It is advised to use `group_materi_plasti_tension` or preferably with `group_materi_plasti_tension_direct` for tension cutoff of large tension stresses. The *index* specifies the element_group, see `element_group`.

7.671 `group_materi_plasti_mohr_coul` *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see `element_group`.

It is advised to use `group_materi_plasti_tension` or preferably with `group_materi_plasti_tension_direct` for tension cutoff of large tension stresses.

7.672 `group_materi_plasti_mohr_coul_direct` *index phi c phiflow*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb plasticity. Choose *phi* and *phiflow* in between 0 and $\frac{\pi}{2}$. The *index* specifies the element_group, see `element_group`.

Principal stress differences higher than allowed by the mohr-coulomb criterium are not allowed and will be cut of by Tochnog. This model uses an alternative programming of the mohr-coulomb law, which tends to be very stable.

You must specify also `group_materi_plasti_tension_direct`.

You can apply softening with a `dependency_diagram` on `materi_strain_total_shear_kappa`.

7.673 `group_materi_plasti_mohr_coul_direct_eps_iter` *index eps_iter*

Relative break tolerance for iterations with the mohr-coulomb direct model. The tolerance in fact states the ratio of the stress change in the last iteration versus the stress change in the first iteration. Default *eps_iter* is set to $1.e - 6$.

7.674 `group_materi_plasti_mohr_coul_hardening_softening` *index phi_0 c_0 phiflow_0 phi_1 c_1 phiflow_1 kappashear_crit*

Both yield data and flow data (indicated by the word flow) for Mohr-Coulomb hardening-softening plasticity. See the theoretical part. Choose each of the angles *phi_0* *phiflow_0* *phi_1* *phiflow_1* in between 0 and $\frac{\pi}{2}$. It is advised to use `group_materi_plasti_tension` or preferably with `group_materi_plasti_tension_direct` for tension cutoff of large tension stresses. The *index* specifies the element_group, see `element_group`.

7.675 `group_materi_plasti_mohr_coul_reduction` *index phi c phi_flow*

With this option you can model interfaces between different materials or between a material and prescribed boundary. This model limits the soil shear stress in the interface with the reduction

factor as specified by **group_materi_plasti_bounda** or **group_materi_plasti_mpc**. The limit of the shear stress follows the classical mohr-coulomb law for interfaces with the specified *phi*, *c* and *phi_flow* (and multiplied by the reduction factor).

This **group_materi_plasti_mohr_coul_reduction** can be combined with the **group_materi_plasti_mohr_coul** record. Then the shear stresses are limited both by the interface law from **group_materi_plasti_mohr_coul** and also by the continuums law from **group_materi_plasti_mohr_coul_direct**.

For all soil elements at which the reduction factor is not active, this **group_materi_plasti_mohr_coul_reduction** will be neglected.

See also **group_materi_plasti_mohr_coul_reduction_method**.

7.676 **group_materi_plasti_mohr_coul_reduction_method** *index dir*

This record works i.c.w. **group_materi_plasti_mohr_coul_reduction**. With this record you can specify the normal direction *dir* for the structure. This *dir* can either be **-x** or **-y** or **-z**. By example, for a vertical pile in 2D you should specify **-x** as normal direction.

Default, if **group_materi_plasti_mohr_coul_reduction_method** is not specified, the *dir* is **-x**.

7.677 **group_materi_plasti_mpc** *index switch*

Same as **group_materi_plasti_bounda**, but now for **mpc....** records however. If you set *switch* to **-yes**, the reduction factor will be applied if there is any mpc at the node of an element.

See also **group_materi_plasti_mpc_factor**.

7.678 **group_materi_plasti_mpc_factor** *index factor*

Same as **group_materi_plasti_bounda_factor**, but now for **group_materi_plasti_mpc** however.

7.679 **group_materi_plasti_pressure_limit** *index pressure_limit*

To prevent plasticity problems near free surfaces, you can require that Tochnog neglects plasticity laws if the pressure exceeds *pressure_limit*. This option is not available for hypoplasticity laws, since for these laws nonlinear elasticity and plasticity are defined by one law, so the plasticity part cannot be suppressed by itself.

7.680 **group_materi_plasti_tension** *index sigy*

Yield data for tension plasticity. The *index* specifies the element_group, see **element_group**. Condition: **materi_strain_plasti** should be initialized.

It is encouraged to use **group_materi_plasti_tension_direct** instead, which tends to give more stable calculations.

7.681 `group_materi_plasti_tension_direct` *index sigy*

Tension limit. Principal stresses higher than *sigy* are not allowed and will be cut off by Tochnog. This model uses directly a cut-off of stresses, and does not use plastic strains. The *index* specifies the element_group, see `element_group`.

You can apply softening with a `dependency_diagram` on `materi_strain_total_tension_kappa`. See also `group_materi_plasti_tension_direct_automatic`.

7.682 `group_materi_plasti_tension_direct_automatic` *index switch*

If *switch* is set to **-yes**, a plastic tension limit is set in the apex of the `group_materi_plasti_mohr_coul_direct` with the same *index*. This actually means a tension limit of $\frac{c}{\tan(\phi)}$.

If you specify `group_materi_plasti_mohr_coul_direct` with the same *index* and no `group_materi_plasti_tension_direct` record, then Tochnog automatically puts *switch* to **-yes** in this `group_materi_plasti_tension_direct_automatic` record.

7.683 `group_materi_plasti_user` *index switch*

If *switch* is set to **-yes** the user supplied routine for plasticity is called.

See also the file `user.cpp` in the distribution.

The *index* specifies the element_group, see `element_group`.

7.684 `group_materi_plasti_visco_exponential` *index γ α*

This record specifies visco-plasticity data for the exponential model. It should be used in combination with a plasticity model.

7.685 `group_materi_plasti_visco_exponential_limit` *index limit*

This record defines the limit for the exponential viscoplasticity argument *alphaf*. If the argument *alphaf* becomes larger than *limit* then actually *limit* will be used instead as argument for the exponent.

Default, if `group_materi_plasti_visco_exponential_limit` is not specified, then 3 will be used as limit.

This record specifies visco-plasticity data for the exponential model. It should be used in combination with a plasticity model.

7.686 `group_materi_plasti_visco_exponential_name` *index name_0 name_1 . . .*

Same as `group_materi_plasti_visco_power_names`, now for the exponential law however.

7.687 `group_materi_plasti_visco_exponential_values` *index* γ_0 α_0 γ_1 α_1 ...

See `group_materi_plasti_visco_exponential_name`.

7.688 `group_materi_plasti_visco_power` *index* η p

This record specifies visco-plasticity data for the power model. It should be used in combination with a plasticity model.

The *index* specifies the element_group, see `element_group`.

7.689 `group_materi_plasti_visco_power_name` *index* *name_0* *name_1* ...

This `group_materi_plasti_visco_power_name` together with `group_materi_plasti_visco_power_value` allows you to specify different viscoelastic parameters for each of the plasticity models.

Set each of the names *name_0* , *name_1* , etc. to the plasticity models that you use (eg - `group_materi_plasti_mohr_coul` etc.) Set the visco parameters for *name_0* in η_0 and p_0 , set the visco parameters for *name_1* in η_1 and p_1 , etc.

In case a plasticity model is used, but is not present in the names *name_0* , *name_1*, etc. then that model will be evaluated elasto-plastic (and thus not elasto-viscoplastic).

The *index* specifies the element_group, see `element_group`.

7.690 `group_materi_plasti_visco_power_value` *index* η_0 p_0 η_1 p_1 ...

See `group_materi_plasti_visco_power_name`.

7.691 `group_materi_plasti_vonmises` *index* σ_{y0}

Yield data for Von-Mises plasticity.

The *index* specifies the element_group, see `element_group`. Condition: `materi_strain_plasti` should be initialized.

7.692 `group_materi_plasti_vonmises_nadai` *index* C κ_0 n

Data for Von-Mises Nadai hardening. The σ_{y0} of the `group_materi_plasti_vonmises` record is taken as σ_{y0} in the nadai law.

The *index* specifies the element_group, see `element_group`. Condition: `materi_plasti_kappa` should be initialized.

7.693 `group_materi_stokes` *index switch*

If *switch* is set to **-yes**, then stokes flow is used. The *index* specifies the `element_group`, see `element_group`.

7.694 `group_materi_umat` *index switch*

If *switch* is set to **-yes** then the user supplied umat routine is called for the element group *index*.

See also the section about user supplied routines at the end of this manual.

7.695 `group_materi_umat_parameters` *index parameter_0 parameter_1 ...*

User supplied parameters for `group_materi_umat`.

7.696 `group_materi_umat_pardiso_decompose` *index switch*

If *switch* is set to **-yes** and an umat routine is present, Tochnog will ask the pardiso solver to decompose the system matrix each and every iteration of each and every timestep. If *switch* is set to **-no** and an umat routine is present, Tochnog will ask the pardiso solver to decompose the system matrix only once (please realise, however, that because of other input file options the decomposition possibly can be done more than once). Default, if *switch* is not defined, it is set to **-yes**.

7.697 `group_materi_undrained_capacity` *index C*

Capacity for undrained analysis. See the theory section for details on undrained analyses.

7.698 `group_materi_viscosity` *index ν*

Dynamic viscosity for nearly incompressible Newtonian flow. The *index* specifies the `element_group`, see `element_group`.

7.699 `group_materi_viscosity_bingham` *index σ_y γ m*

Parameters for the non-Newtonian Bingham viscosity law. The *index* specifies the `element_group`, see `element_group`.

7.700 `group_materi_viscosity_exponential` *index ν_0 m*

Parameters for the non-Newtonian exponential viscosity law. The *index* specifies the `element_group`, see `element_group`.

7.701 **group_materi_viscosity_heatgeneration** *switch*

If *switch* is set to **-yes**, then viscous dissipation will be used as a heat generation source. See also the theoretical part at the start of this manual. The *index* specifies the **element_group**, see **element_group**.

7.702 **group_materi_viscosity_user** *index switch*

If *switch* is set to **-yes**, the user supplied routine for the viscosity for Newtonian flow is used. The *index* specifies the **element_group**, see **element_group**.

7.703 **group_plasti_apply** *index switch*

If *switch* is set to **-no** any plasticity data in the group *index* will be neglected. Default, if **group_plasti_apply** is not specified, *switch* is set to **-yes**.

7.704 **group_porosity** *index n*

Porosity in material. By example needed for **group_groundflow_nonsaturated_vangenuchten**. The *index* specifies the **element_group**, see **element_group**.

7.705 **group_spherical** *index switch*

If *switch* is set to **-yes**, the calculation becomes spherical for the group *index*. Each specified *x* coordinate becomes a radius and *y* becomes the ϕ direction and the *z* becomes the θ direction. Specify only positive *x* coordinates (thus only a radius), and no *y* and *z* coordinates.

7.706 **group_spring_direction** *index dir_x dir_y dir_z*

Direction of a spring. If for a **-spring2** this record is not specified, the direction is taken to be from the first node of the spring to the second node. The *index* specifies the **element_group**, see **element_group**.

7.707 **group_spring_memory** *index memory_type*

Memory model for spring; either **-updated_linear**, **-total_linear** or **-updated**. The **-updated** model is a geometrically nonlinear model which takes large spring rotations into account for two-noded springs. The *index* specifies the **element_group**, see **element_group**.

7.708 **group_spring_plasti** *index F_y*

Maximum force in a spring. The *index* specifies the **element_group**, see **element_group**.

7.709 **group_spring_stiffness** *index k*

Stiffness of a spring. It is multiplied with the elongation of the spring to calculate the spring force. The *index* specifies the element_group, see **element_group**.

7.710 **group_spring_stiffness_nonlinear** *index epsilon₀ k₀ epsilon₁ k₁ ...*

Diagram with spring stiffness dependent on total spring strain (= total spring elongation). Here *epsilon₀* *k₀* is the first point in the diagram, with *epsilon₀* the total spring strain and *k₀* the spring stiffness. Likewise for the next points in the diagram. Take care that you specify diagram values with a strain range that includes all spring strain that actually occur in the calculation.

The *index* specifies the element_group, see **element_group**.

7.711 **group_time** *index birth death*

With this option you can set the time of birth of the elements (in group *index*) and the time of death of the elements.

Out of the range *birth* - *death* the elements of the group will not be used in the calculation (the starting *birth* limit itself is not included in the range, whereas the ending *death* limit itself is included).

7.712 **group_time_fill** *index birth_empty birth_filled death*

With this option you can set the time of birth of the elements (in group *index*) and the time of death of the elements.

Out of the range *birth_empty* - *death* the elements of the group will not be used in the calculation (the starting *birth_empty* limit itself is not included in the range, whereas the ending *death* limit itself is included).

Between *birth_empty* and *birth_filled* the elements will be 'slowly filled with material'. This means that the density of the element and the total pressure (pore pressure), in case groundflow is present, will be scaled with a factor 0 at time *birth_empty* up to a factor 1 at time *birth_filled*. To prevent numerical problems at low gravity, any plasticity data will be ignored when an element is being filled; after the element is completely filled plasticity will become active (plasticity data will be applied).

7.713 **group_truss_area** *index A*

Cross-sectional area for a truss. The *index* specifies the element_group, see **element_group**.

7.714 **group_truss_bond_slip_ceb_fip_1990** *index s_1 s_2 s_3 tau_max tau_f alpha*

Parameters for the CEB-FIP Model Code 90 bond slip model. See also the theory section.

7.715 `group_truss_bond_slip_diagram` *index s_0 tau_b,0 s_1 tau_b,1 ...*

Bond slip diagram, specifying the maximum shear stress as function of the shear slip. See also the theory section.

7.716 `group_truss_density` *index ρ*

Density for a truss. The *index* specifies the `element_group`, see `element_group`.

7.717 `group_truss_elasti_elongation_force_diagram` *index l_0 F_0 l_1 F_1 ...*

With this record you can specify a force versus elongation diagram for a truss. Here each l_i is the ratio of the truss elongation divided by the initial truss length. And each F_i is the corresponding force. This `group_truss_elasti_elongation_force_diagram` cannot be combined with `group_truss_elasti_young`.

7.718 `group_truss_elasti_young` *index E*

Young's modulus for a truss. The truss force F is $F = EA\Delta u$, where Δu is the elongation of the truss. The *index* specifies the `element_group`, see `element_group`.

See also `group_truss_area`.

7.719 `group_truss_expansion` *index α*

Thermal expansion coefficient for trusses. A temperature increment dT leads to a thermal incremental length of the size $\alpha * dT * \text{initial length}$;

7.720 `group_truss_initial_force` *index initial_force*

Initial truss force in truss elements.

7.721 `group_truss_memory` *index memory_type*

Memory model for truss; either `-updated_linear`, `-updated` or `total_linear`. The `-updated` model is a geometrically nonlinear model which takes large truss rotations into account. The *index* specifies the `element_group`, see `element_group`.

7.722 `group_truss_perimeter` *index p*

Perimeter for a truss, by example $2 * \Pi * \text{radius}$ for a circular truss. This is only required for truss bond slip calculations.

7.723 **group_truss_rope** *index switch*

The truss will act as a rope if *switch* is set to **-yes**. This means that negative forces will not be allowed (the force remains zero in compression). The *index* specifies the element_group, see **element_group**.

7.724 **group_truss_plasti** *index σ_c σ_t*

Compressive and tension yield stress for truss. The actual stress cannot become lower than the σ_c in compression, and the actual stress cannot become higher than the σ_t in tension. The *index* specifies the element_group, see **element_group**.

7.725 **group_type** *index type_name_0 type_name_1 ...*

With this record a differential equation is specified for the element group *index*. Allowed type names are **-condif**, **-groundflow**, **-materi**, **-wave**, **-spring**, **-contact_spring**, **-truss**, **-beam**, **-truss_beam** and **-hinge**. Also **-empty** is allowed; it indicates that the element is empty.

For the **-truss_beam** type you need to set parameters with **group_truss_*** and **group_beam_*** records. For the **-truss** type you need to set parameters with **group_truss_*** records. For the **-beam** type you need to set parameters with **group_beam_*** records. For the **-condif** type you need to set parameters with **group_condif_*** records. For the **-materi** type you need to set parameters with **group_materi_*** records. Etc etc.

See also **element_group**.

7.726 **group_volume_factor** *index factor*

In 1D or 2D you can specify the cross-section and thickness respectively, for elements of the element group *index* (see **element_group**).

See also **volume_factor**.

7.727 **group_wave_speed_of_sound** *index c*

Speed of sound in wave equation. The *index* specifies the element_group, see **element_group**.

7.728 **icontrol** *icontrol*

With this record you can set the control index which already have been performed. Thus if you set it to 10, all **control_*** records up to and including those with index 10 will be skipped, and the control indices starting from 11 will be performed.

7.729 **inertia_apply** *switch_0 switch_1 ...*

If *switch_0* is set to **-yes**, the corresponding inertia term is included (material mass, heat capacity, ..). The same for the other switches. A switch should be specified for each of the principal dof's. See the 'input file - data part - introduction - types of dof's' section for an explanation about

principal dof's. The sequence of the principal dof's is in the order as initialised in the **initia ... end_initia** part.

As a special option you can specify only one switch, and then the specified value will automatically be used for all principal dof's.

This **inertia_apply** is applied for all timestep records.

Default, if **inertia_apply** is not specified, then each of *switch_0*, *switch_1* etc. is set to **-no**.

See also **control_inertia_apply**.

7.730 **input_abaqus** *switch*

Set *switch* to **-yes** for reading the abaqus input file **abaqus.inp**. Tochnog will use it to generate a tochnog input file **tochnog_abaqus.dat**. This can typically be done by making an input file like:

```
...
echo -yes
number_of_space_dimensions 3
materi_velocity
materi_stress
end_initia
input_abaqus -yes
input_abaqus_continue -yes
...
include tochnog_abaqus.dat
...
( other data , you can use the abaqus sets of tochnog_abaqus.dat )
...
end_data
```

You need to initialise the fields like **materi_velocity**, **materi_stress**, etc that you will actually use later in the calculation. Only a limited set of data is transferred from the abaqus input file to the tochnog input file; you need to check if the Tochnog input file is like you want. ABAQUS element sets and node sets are evaluated and can be used in the tochnog calculation.

ABAQUS is a registered trademark or trademark of Dassault Systemes.

7.731 **input_abaqus_continue** *switch*

If *switch* is set to **-yes** then after **tochnog_abaqus.dat** is generated the remainder of the input file read and the calculation continues. If *switch* is set to **-no** then after **tochnog_abaqus.dat** is generated the remainder of the input file will not be read and the calculation aborts. The **input_abaqus_continue** record should always be present as last record of the **input_abaqus_*** records.

7.732 **input_abaqus_group** *switch*

If *switch* is set to **-yes** then also **group_*** is written to **tochnog_abaqus.dat**. If *switch* is set to **-no** then no **group_*** is written to **tochnog_abaqus.dat**. So you can set *switch* to **-no** in case

you want to provide the **group_*** yourself, and don't want it to be taken from the **abaqus.inp**.

Default, if **input_abaqus_group** is not specified, the *switch* is set to **-yes**.

7.733 **input_abaqus_set** *set_0 set_1 ...*

With this option you can specify for which set numbers the elements should be written. See the generated **tochnog_abaqus.dat** for the set numbers.

7.734 **input_abaqus_name** *name_0 name_1 ...*

With this option you can specify which abaqus element types should be converted into tochnog elements. By example specify **-tria3** if you want to include **tria3** elements in the Tochnog input file. In case you do not specify **input_abaqus_name** all elements will be converted into tochnog elements. However, not all abaqus elements are available as tochnog element; if a non-available element is encountered it will be skipped.

7.735 **input_gmsh** *switch*

This option is under development.

Set *switch* to **-yes** for reading the **gmsh** mesh file **tochnog_in.msh**. Only linear and quadratic elements are read.

The **gmsh** program is a free external pre- and postprocessor. See <http://www.geuz.org/gmsh> .

Only the data **element**, **element_group** and **node** is read.

7.736 **interface_gap_apply** *switch*

If *switch* is set to **-yes** then any **group_interface_gap** will be applied. If *switch* is set to **-no** then any **group_interface_gap** will be ignored.

Default, if **interface_gap_apply** is not specified, *switch* is set to **-yes**.

This **interface_gap_apply** record will be overruled by the **control_interface_gap_apply** record if specified.

7.737 **license_wait** *switch*

If *switch* is set to **-yes** tochnog waits till a valid license is found on the computer. So the calculation will not be aborted if no valid license is found.

Default *switch* is set to **-no** and the calculation will be aborted if no valid license is found.

7.738 **linear_calculation_apply** *switch*

If you set the *switch* to **-yes**, Tochnog will skip nonlinearities from the input file. This option is convenient for testing and problem search. Simple set **linear_calculation -yes** so that the cal-

ulation should run without any trouble, and use a **control_print** for **-post_node_rhside_ratio**. The printed **-post_node_rhside_ratio** should be very small, typically 1.e-10 or lower, since the calculation is linear now. If that is not the case, there may be a problem with the boundary conditions or some other problem.

A typical sequence for testing very large calculations may be following: first run with **solver -none** and check the mesh at all times; second run with **linear_calculation_apply -yes** to check if good linear solutions fields are obtained (check the linear results carefully); finally run your actual calculation without any special options.

The following specific actions are taken:

- Any **control_plasti_apply** is deleted, and **plasti_apply** is set to **-no**.
- **mesh** is set to **-fixed_in_space**.
- For all **group_*_memory** the memory type is set to **-total_linear** if **materi_displacement** is initialised, and it is set to **-updated_linear** otherwise.
- Any **dependency_item** , **dependency_diagram** containing **group_*** data depending on one of the dof's of **dof_label** is deleted.
- Any **group_materi_elasti_hardsoil** is deleted and substituted by a **group_materi_elasti_young** with *E50ref* as Young's modulus.
- Any **group_materi_elasti_polynomial** is deleted and substituted by a **group_materi_elasti_young** with *E0* as Young's modulus.
- Any **group_materi_elasti_young_power** is substituted by a linear **group_materi_elasti_young**.
- Any **group_materi_plasti_hypo_wolffersdorff** is deleted and substituted by a **group_materi_elasti_young** with *hs* as Young's modulus, and a **group_materi_elasti_poisson** with value 0.2.
- Any **group_spring_stiffness_nonlinear** is deleted and substituted by a **group_spring_stiffness** with the stiffness value at strain 0.
- Any **group_groundflow_nonsaturated** is deleted.
- Any **group_interface_gap** is deleted.
- Any **group_interface_materi_hardening** is deleted.
- Any **group_interface_materi_elasti_stiffness_tangential_diagram** is deleted.
- Any **group_materi_damage** is deleted.
- Any **group_materi_failure** is deleted.
- Any **group_truss_rope** is deleted.
- Any **contact_*** is deleted.
- Any **groundflow_seepage_*** is deleted.

7.739 **materi_damage_apply** *switch*

If *switch* is set to **-no**, any damage data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with damage data. See also **control_materi_damage_apply**.

7.740 **materi_elasti_young_power_apply** *switch*

If *switch* is set to **-no**, any nonlinearity in young dependent on a power law will be ignored; simply the reference young as encountered in the **group_materi_elasti_young_power** records will be applied at all times.

7.741 **materi_failure_apply** *switch*

If *switch* is set to **-no**, any failure data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with failure data. See also **control_materi_failure_apply**.

7.742 **materi_plasti_hypo_substepping** *index switch*

If *switch* is set to **-yes** substepping will be applied in hypoplasticity routines. If *switch* is set to **-no** substepping will not be applied in hypoplasticity routines.

If the record **control_materi_plasti_hypo_substepping** is specified that record will be used. If none record is not specified *switch* is set to **-yes**.

7.743 **materi_plasti_max_iter** *max_iter*

With this record you can set the maximum number of plastic iterations that will be used on integration point level. Default *max_iter* is 1000.

This option is convenient to view plastic high risk zones in gid using a simple linear elastic calculation. To do so, perform a gravity stress calculation with all plastic data included in the input file, initialise **materi_plasti_f** in the initialisation part, and further use **materi_plasti_max_iter 0**. Then view in gid the contour plot of **materi_plasti_f**; zones with high plastic f values have the highest risk of plastic failure.

7.744 **materi_plasti_visco_apply** *switch*

If *switch* is set to **-no**, any visco-plasticity data in the input file will be ignored. This is done for all timesteps.

See also **control_materi_plasti_visco_apply**.

7.745 **mesh** *specifier_x specifier_y specifier_z*

If *specifier_x* is set to **-fixed_in_space**, the nodal points of the mesh remain fixed in space in x-direction. If a *specifier_x* is set to **-follow_material**, the nodal points of the mesh will follow material displacements in x-direction. The same holds for the other directions. In 1D, you only need to give *specifier_x*, etc.

Default each specifier is set to **-fixed_in_space**.

This record **mesh** only is used if **materi.velocity** is initialised. If **materi.displacement** is initialized each specifier is automatically set to **-fixed_in.space**.

7.746 mesh_activate_gravity_element *index element_range*

See **mesh_activate_gravity_time**.

7.747 mesh_activate_gravity_element_group *index element_group_0 element_group_1*
...

See **mesh_activate_gravity_time**.

7.748 mesh_activate_gravity_geometry *index geometry_item_name geometry_item_index*

See **mesh_activate_gravity_time**.

7.749 mesh_activate_gravity_method *index method*

Set to **-method1** or **-method2**. Default Tochnog will use **-method2**.

See **mesh_activate_gravity_time**.

7.750 mesh_activate_gravity_plasti_apply *index switch*

See **mesh_activate_gravity_time**.

7.751 mesh_activate_gravity_stiffness_factor *index factor*

See **mesh_activate_gravity_time**.

7.752 mesh_activate_gravity_time *index time_start time_end*

With this record you can slowly activate gravity for elements between *time.start* and *time.end*.

You can specify an element range with **mesh_activate_gravity_element**. The elements you need to specify as elements range. Possible formats for the elements are a number (eg. 5), a number range (eg. **-ra** 5 4 8 **-ra**), or all elements (**-all**).

Or otherwise, you can specify element group numbers with **mesh_activate_gravity_element_group**.

Or otherwise, you can specify a geometry with **mesh_activate_gravity_geometry** so that elements completely in the geometry will be used.

Tochnog will activate the elements from the bottom to the top. For each specific element the start time of activation is interpolated from the global *time.start* and *time.end* and the lowest coordinate of the element. Likewise, for the element end time of activation the highest coordinate is used.

Typically take care that the timestep is so small that each timestep only about 10 percent of an element gets filled.

This option comes handy to slowly build dams or so, starting at the bottom and building upwards to the top.

If **mesh_activate_gravity_method** is set to **-method1**, before the element start time of activation, the element is not active in the calculation. After the element end time of activation, the element is fully active in the calculation. Between these times the element is active, but the gravity is 0 at the element start time of activation, the gravity gets its full value at the element end time of activation, and the gravity is interpolated in between. With this **-method1** the displacements for activated nodes are 0 at the moment of activation, and grow later in time. Thus the displacements in the activation area are relative to the moment of material activation, and not relative to the moment of start of the calculation.

If **mesh_activate_gravity_method** is set to **-method2**, before the element start time of activation, the element is active in the calculation, but has no gravity force yet. After the element end time of activation, the element is fully active in the calculation with full gravity force. Between these times the element is active, but the gravity is 0 at the element start time of activation, the gravity gets its full value at the element end time of activation, and the gravity is interpolated in between. With this **-method2** the displacements for activated nodes are not 0 at the moment of activation, but already have values resulting from activation of material below. For elements which are not activated yet, Tochnog will reduce the stiffness so that it will not really influence displacements inside the elements which are already being activated; the stiffness reduction factor can be specified by **mesh_activate_gravity_stiffness_factor**, and is 1.e-6 by default. For elements which are not activated yet, Tochnog will not print the elements to the gid postprocessing files; however you can demand that these elements will also be printed by specifying **-yes** in **print_gid_mesh_activate_gravity** or **control_print_gid_mesh_activate_gravity** (default **-no**).

For both methods any plasticity data in elements will be neglected until *time_end* is reached. However, you can require that plasticity data is used all the time by setting **mesh_activate_gravity_plasti_apply** to **-yes**.

You can set with **mesh_activate_gravity_time_initial** when elements become active in a calculation; before the specified *time_of_birth* an element will not take part of the calculation.

See also **control_mesh_activate_gravity_apply**.

7.753 **mesh_activate_gravity_time_initial** *index time_of_birth*

See **mesh_activate_gravity_time**.

7.754 **mesh_activate_gravity_time_strain_settlement** *index switch*

If *switch* is set to **-yes** then strain settlement should be used for the **mesh_activate_gravity_time** record with the same index.

7.755 **mesh_boundary** *switch*

If *switch* is set to **-yes**, Tochnog determines the boundary of the mesh and sets **node_boundary** records. If *switch* is set to **-no**, Tochnog does not determine the boundary of the mesh. Default, if **mesh_boundary** is not present, the *switch* is set to **-yes**.

7.756 **mesh_correct** *switch*

If *switch* is set to **-yes**, Tochnog checks that the connectivity list for quadrilateral and hexahedral interfaces and hinges is correct. If the connectivity list would not be correct (that is, according to the required sequence in Tochnog for such elements), the connectivity list will be corrected.

Default *switch* is set to **-no**.

7.757 **mesh_correct_reference_point** *x y z*

When applying **mesh_correct** to 3D hinges, the node connectivity needs to be made such by Tochnog that the hinge length direction points as much as possible in a specific direction (by example the tunnel radial direction). In order to do so, you need to specify this reference point (think of it as the tunnel middle); Tochnog will then make the element connectivity such that the length direction points as much as possible to that reference point.

7.758 **mesh_interface_triangle_coordinates** *index coord_x_0 coord_y_0 coord_z_0 coord_x_1 coord_y_1 coord_z_1 coord_x_2 coord_y_2 coord_z_2 ...*

With this option you can generate interface elements in a 3d mesh with tet4 elements. You specify the triangulated plane of the interface as sets of triangles in 3d space. For each triangle you specify for the three corner points the coordinates. By example *coord_x_0 coord_y_0 coord_z_0* are the coordinates of the first corner point, *coord_x_1 coord_y_1 coord_z_1* are the coordinates of the second corner point and *coord_x_2 coord_y_2 coord_z_2* are the coordinates of the third corner point. The combination of all triangles specifies the plane which will be intersected with the 3d tet4 mesh to generate the interface elements.

With **mesh_interface_triangle_element_group** you specify the group which will be attributed to the interface elements. With **control_mesh_interface_triangle** you specify the control index for which the generation should be done.

A typical input file looks like:

```
...
group_type 1 -materi
group_interface 1 -yes
group_interface_materi_memory 1 -total_linear
group_interface_materi_elasti_stiffness 1 1.e11 0.5e11 0.5e11
...
mesh_interface_triangle_coordinates 0. 0. 0.6 100. 0. 0.6 0. 100. 0.6
mesh_interface_triangle_element_group 1
...
control_mesh_interface_triangle 10 -yes
...
```

7.759 **mesh_interface_triangle_element_group** *index element_group*

See **mesh_interface_triangle_coordinates**.

7.760 **mpc_element_group** *index element_group_0 element_group_1*

Each node of element of group *element_group_0* that is also located in an element of group *element_group_1* will be tied to that group by means of multi point constraints. The multi point constraints will be consistent with the shape functions at the specific isoparametric coordinates of the location of that node in the element of group *element_group_1*. For *element_group_1* you can only use isoparametric elements.

See also **mpc_element_group_always** and **control_mpc_element_group**.

7.761 **mpc_element_group_always** *index switch*

If *switch* is set to **-yes** the mpc's will be generated always. If *switch* is set to **-no** the mpc's will only be generated if the considered node is not a member of the node list of the element of group *element_group_1* (this ensures that mpc's will only be generated if the node is completely loose from the other element). You can use the *switch* is **-no** option if you are not sure if *element_group_0* is connected to, or not connected to, *element_group_1*; with **-no** you will not get mpc's if the groups are connected; see **mpc_*** in the dbs file to check if mpc's are generated. So if you are not sure if surfaces are connected in gid, a typical strategy would be:

- run tochnog with **mpc_element_group ...** and **mpc_element_group_always -no**
- if you get **mpc_*** records in the dbs, run again with **mpc_element_group ...** and **mpc_element_group_always -yes**
- if you do not get **mpc_*** records remove **mpc_element_group** and **mpc_element_group_always**

Default, if **mpc_element_group_always** is not specified, *switch* is set to **-yes**.

7.762 **mpc_element_group_dof** *index dof_0 dof_1 ...*

The *dof_0 dof_1 ...* in **mpc_element_group_dof** specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc. Default, if **mpc_element_group_dof** is not specified, all principal dofs will be set equal.

7.763 **mpc_element_group_eps_iso** *index eps*

With *eps* you can specify the tolerance on the isoparametric coordinates for the element of *element_group_1* below which a node of *element_group_0* is considered to be located in *element_group_1*. Default, if **mpc_element_group_eps_iso** is not specified, *eps* is set to **1.e-4**.

7.764 **mpc_element_group_geometry** *index geometry_entity_item geometry_entity_index*

Select a geometry for nodes of *element_group_0*.

7.765 **mpc_geometry** *index geometry_entity_item_0 geometry_entity_index_0 geometry_entity_item_1 geometry_entity_index_1*

See also **mpc_geometry_method**.

If *method* in **mpc_geometry_method** is set to **-method0** the following mpc's will be generated. This record automatically generates **mpc_node_number** and **mpc_node_factor** records such that dof's in the second geometry *geometry_entity_item_1 geometry_entity_index_1* become equal to the dof's in the first geometry *geometry_entity_item_0 geometry_entity_index_0*. The *switch_x switch_y switch_z* in **mpc_geometry_switch** specify the coordinates that should be checked to judge if a node in the second geometry is considered to have the same position as a node in the first geometry, and thus should get the same dof's. Only the coordinate for which the corresponding switch is set to **-yes** will be checked. By example in 3D if **-yes -no -no** are used then a node in the second geometry gets the same dof's of a node in the first geometry in it has (almost) equal x-coordinate; the y and z-coordinate are irrelevant. In 2D only *switch_x switch_y* need to be specified. With **mpc_geometry_tolerance** you can set the tolerance beneath which nodes of the first geometry and second geometry are assumed to have the same coordinate. If **mpc_geometry_tolerance** is not specified then a tolerance of 1.e-4 is used.

If *method* in **mpc_geometry_method** is set to **-method1** the following mpc's will be generated. You should only specify the first geometry. The dof's of the nodes in this first geometry become equal. The first node of this first geometry becomes the master, all other nodes in this first geometry become slave. If you want to know which node is the first node in this first geometry, use a **control_print ... -node** with a **print_filter** for the first geometry.

If *method* in **mpc_geometry_method** is set to **-method2** the following mpc's will be generated. You should only specify the first geometry. Unknowns of the nodes with equal coordinate in this first geometry become equal.

7.766 **mpc_geometry_method** *index method*

See **mpc_geometry**. If this **mpc_geometry_method** is not specified then *method* will be set to **-method0**.

7.767 **mpc_geometry_switch** *index switch_x switch_y switch_z*

See **mpc_geometry**.

7.768 **mpc_geometry_tolerance** *index tolerance*

See **mpc_geometry**.

7.769 **mpc_geometry_dof** *index dof_0 dof_1 ...*

The *dof_0 dof_1 ...* in **mpc_geometry_dof** specify the dof's that should be set equal, e.g. **-velx**, **-vely** etc.

7.770 **mpc_linear_quadratic** *switch*

If *switch* is set to **-yes** this option is activated.

If you have a mesh with both linear elements and quadratic elements, the mesh is not compatible at the places where the linear elements and quadratic elements meet at a common interface. There some of the quadratic element nodes are not attached to the linear elements, and so non-compatible solution fields occur.

This **mpc_linear_quadratic** option allows you to automatically prevent the non-compatible solution fields. Tochnog imposes a multi point constraint on all non-compatible solution fields between the linear and quadratic elements, so that the extra nodes of the quadratic elements are forced to follow the solution field of the linear elements, and so compatibility is ensured again.

This option typically can be used to model structural parts like beams, sheet piles, tunnel shells etc with quadratic elements, and the surrounding soil with linear element. Use one quadratic element in the structural part thickness direction, and extra one quadratic soil element attached to the structural element. For the remaining soil elements use linear elements. In this way, the stiff structural elements can deform flexible enough, and you save computer time by modeling most of the soils with linear elements.

7.771 mpc_node_factor *index factor_10 factor_11 ... factor_20 factor_21 ...*

See **mpc_node_number**.

7.772 mpc_node_number *index node_0 dof_0 node_1 dof_10 dof_11 ... node_2
dof_20 dof_21 ...*

This Multi Point Constraint record **mpc_node_number** allows you to set constraints between dof's at different nodes. The *dof_0* specifies the dof at node number *node_0* which will be constrained. It will be constrained to dof's *dof_10*, *dof_11*, ... of *node_1* and *dof_20*, *dof_21*, ... of *node_2*, etc. Only principal dof's can be specified. Principal dof's are material velocities, groundflow pressure, temperature in the convection diffusion equation, etc.; see the start of the data section for a definition of principal dof's. With **mpc_node_factor** you can set multiplication factors for the constraints. If you don't specify **mpc_node_factor** a 1 is used for all factors.

Example:

```
...
mpc_node_number 10 1 -velx 2 -velx 3 -vely
mpc_node_factor 10 7. 9.
```

In this example the $velx_1 = 7. * velx_2 + 9. * vely_3$ where *velx_1* is the x-velocity at node 1 etc. Node number *node_0* is this slave node which depends on nodes *node_1* etc. which are the master nodes.

Boundary conditions with **bounda_dof** and **bounda_time** cannot be specified for slave nodes.

See also **mpc_geometry** for easy generation of multi point constraints.

7.773 node *index coord_0 coord_1 coord_2*

Coordinates of node *index*. In 1D, only *coord_0* should be specified, etc..

You are not allowed to put free nodes (not attached to any element) in your model. These free nodes will be removed automatically.

7.774 node_bounded *index indicator_dof_0 indicator_dof_1 ...*

This record is for printing only, it is not an input record. This record indicates if dof's in the node are bounded via a **bounda_dof** record; then the corresponding indicator is set to 1, else it remains 0.

7.775 node_bounded_index *index bounda_dof_index_0 bounda_dof_index_1 ...*

This record is for printing only, it is not an input record. This record list the index of the **bounda_dof** record by which the dof's are bounded. This index is only filled if the dof's really bounded, so if the corresponding value in the **node_bounded** record is set to 1.

7.776 node_damping *index damping_x damping_y damping_z*

This record adds a discrete damper to node *index* in *x*, *y* and *z* direction respectively. In 1D only *damping_x* needs to be specified, etc. The damper will lead to a nodal force of the size *damping_x * v_x* where *v_x* is the velocity in *x* direction. The same holds for the *y* and *z* direction.

7.777 node_dof *index dof_0 dof_1 ...*

dof_0 dof_1 ... are the degrees of freedom (dof's) at the node with number *index*. The total number and type of the dof's depends on the initialization part. Each node has the same dof's.

Unknowns like pressure, temperature, etc. are primary dof's. The other dof's, space derivatives and the time derivative, are not primary dof's. In the example below, **-temp** is 1., **-xtemp** is 0.2 and **-ttemp** is 0.1 in node 6

```
...
number_of_space_dimensions 1
derivatives
condif.temperature
end_initia
...
node_dof 6 1.0 0.2 0.1
...
```

Default all values in the **node_dof** records are set zero at the start of the calculation.

These **node_dof** records contain principal dof's for all elements (displacements, temperatures, etc). Other dof's like strains, stresses etc. are only filled for the normal isoparametric elements; thus, by example, strain and stress results for interfaces elements are not placed in the **node_dof** records.

See also: **dof_label** and **post_point**.

7.778 node_dof_calcul *index ...*

See **post_calcul**.

7.779 node_dof_start_refined *index dof_0 dof_1 ...*

This record will be filled with *dof_0 dof_1 ...*, which are the degrees of freedom (dof's) as specified at the start of the calculation. at the node with number *index*.

If the mesh has been refined, these start values hold for the refined mesh.

See also **node_dof** and **node_start_refined**.

7.780 node_force *index force_x force_y force_z*

With this record you can input a discrete nodal force at node *index*. In 1D you only should specify the force in x-direction. In 2D you only should specify the force in x- and y-direction.

7.781 node_geometry_present *index geometry_item_name_0 geometry_item_index_0
geometry_item_name_1 geometry_item_index_1 ...*

This record lists for node *index* the geometries in which it is present. So it is a print record only, for checking if the geometries include exactly the nodes that you want. You can switch on or off filling of these records by setting **print_node_geometry_present** to **-yes** or **-no**.

7.782 node_inertia *index inertia_dof_0 inertia_dof_1 ...*

This record will be filled with calculated inertia terms degrees of freedom (dof's) as specified at the start of the calculation. at the node with number *index*. For material velocity that is the mass inertia term in the node.

7.783 node_mass *index mass_x mass_y mass_z*

This record adds a discrete mass to node *index* in *x*, *y* and *z* direction. In 1D only the *x*-mass needs to be specified, etc. The mass will lead to a nodal force of the size $mass_x * \dot{v}$ where \dot{v}_x is the acceleration, and to a gravity force if **force_gravity** is specified. The same holds for the *y* and *z* direction.

7.784 node_mesh *index ...*

Same as **mesh**, but now specified per node however. The *index* specifies the node number. If this **node_mesh** record is specified for a node, it overrules the **mesh** record.

7.785 node_rhside *index rhside_0 rhside_1 ...*

This record will contain after the calculations

$$F_{\text{external}} - (F_{\text{static}} + F_{\text{inertia}})$$

Here F_{external} are the external forces resulting from **bounda.force** records, F_{static} are the internal static forces (elastic forces, damping, element loads, ..), F_{inertia} are the internal inertia forces (mass, capacity, ..).

For the temperature equation, this will give the heat flow normal to the outer surface (the heat flux to the environment) at prescribed temperatures. For velocity dof's, this will give the force vector at prescribed displacements. For the pressure in the ground flow equation, this will give the ground flow to the environment at prescribed pressures.

The *index* is the node number.

7.786 **node_slide** *index slide_number*

With **node_slide** you can specify of a specific node *index* if it belongs to a sliding geometry with index *slide_number*. For the sliding geometry **slide_geometry** is not needed anymore because the **node_slide** already specifies which nodes belong to the sliding geometry.

7.787 **node_start_refined** *index coord_0 coord_1 coord_2*

After the calculation, this record will contain coordinates of node *index* as specified at the start of the calculation. If the mesh has been refined this record will contain the start coordinates for the refined mesh. In 1D, only *coord_0* is filled, etc..

7.788 **node_stiffness** *index stiffness_x stiffness_y stiffness_z*

This record adds a discrete stiffness to node *index* in *x*, *y* and *z* direction respectively. In 1D only *stiffness_x* needs to be specified, etc. The stiffness will lead to a nodal force of the size *stiffness_x * u_x* where *u_x* is the displacement in *x* direction. The same holds for the *y* and *z* direction. Condition: also **materi_velocity_integrated** or **materi_displacement** should be initialized.

7.789 **node_support_edge_normal_plasti_tension_status** *index status*

This record will contain after a calculation the status of a node for the **support_edge_normal_plasti_tension** or **support_edge_normal_plasti_tension_double** option. If the node is opened due to tension plasticity the status is set to **-opened**. If the node is closed the status is set to **-closed**.

7.790 **nonlocal** *nonlocal_radius*

By specifying this record in combination with a viscoplastic model, like **group_materi_plasti_visco_power**, a nonlocal yield rule *fn* will be used in the viscoplastic law. The nonlocal yield rule needs to be initialized as dof by the **materi_plasti_f_nonlocal** record in the initialization part. The nonlocal yield rule *fn* in a point is determined by an averaging of the local yield rule *f* in neighboring points and using gauss weighting functions for this (i.e. the larger the distance the less the neighboring point contributes to the nonlocal yield rule). The averaging is done over a region with radius *nonlocal_radius*.

In this way, you can prevent unlimited localization and so mesh dependency, in calculations with softening plasticity.

See also **nonlocal_name**.

7.791 **nonlocal_name** *name*

With *name* you specify the name of the plasticity model that should be treated nonlocal, eg **group_materi_plasti_mohr_coul**. You can only specify one name, so only one plasticity model can be used as nonlocal model.

7.792 **plasti_apply** *switch*

If *switch* is set to **-no**, any plasticity data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with plasticity data. See also **control_plasti_apply**.

7.793 **post_calcul** *dofoperat* ...

This records activates calculation post results. Here *dof* can be one of the matrices

- materi_stress**,
- materi_strain_elasti**,
- materi_strain_plasti**,
- materi_strain_plasti_compression**,
- materi_strain_plasti_diprisco**,
- materi_strain_plasti_druckprag**,
- materi_strain_plasti_hardsoil**,
- materi_strain_plasti_laminate0_mohr_coul**, (or one of the other laminates)
- materi_strain_plasti_laminate_mohr_coul**, (for the sum of the laminates)
- materi_strain_plasti_laminate0_tension**, (or one of the other laminates)
- materi_strain_plasti_laminate_tension**, (for the sum of the laminates)
- materi_strain_plasti_tension**,
- materi_strain_plasti_vonmises**,
- materi_strain_total** or *dof* can be one of the vectors **-materi_velocity**, **-materi_displacement**,
- or *dof* can be one of the scalars **-condif_temperature**, **-groundflow_pressure**.

The results of these calculations are stored for each **node_dof** record in a **node_dof_calcul** record, and are stored for each **post_point_dof** record in a **post_point_dof_calcul** record, and are stored for each **post_line_dof** record in a **post_line_dof_calcul** record, and are stored for each **post_quadrilateral_dof** record in a **post_quadrilateral_dof_calcul** record.

We denote a matrix *dof* with A_{ij} and denote a vector *dof* with A_i , and denote a scalar *dof* with a . If *operat* is **-absol** then the absolute value of a scalar a is calculated.

If *operat* is **-average** then $\frac{1}{3}(A_{11} + A_{22} + A_{33})$ is calculated for a matrix or $\frac{1}{3}(A_1 + A_2 + A_3)$ is calculated for a vector.

If *operat* is **-negative** then the average of the negative principal values for a matrix is calculated. If **materi_strain_plasti** is taken for the matrix A_{ij} , then this operator typically can be used as a measure for the amount of compression failure (crunching).

If *operat* is **-positive** then the average of the positive principal values for a matrix is calculated. If **materi_strain_plasti** is taken for the matrix A_{ij} , then this operator typically can be used as a measure for the amount of tensile failure (cracking).

If *operat* is **-prival** then three principal values of a matrix A_{ij} are calculated. Each principal value contains the size of the principal vector. The principal values are ordered (the first value is the smallest one, and the last value is the largest one).

If *operat* is **-privec** then three principal vectors of a matrix A_{ij} are calculated. Each principal vector contains the x , y and z component of the principal vector. The same ordering as used for **-prival** is used here also.

If *operat* is **-size_tot** then $\sqrt{A_{ij}A_{ij}}$ is calculated for a matrix or $\sqrt{A_iA_i}$ is calculated for a vector. This measures the size of a matrix or the size of a vector.

If *operat* is **-size_dev** then $\sqrt{B_{ij}B_{ij}}$ is calculated where B_{ij} is the deviatoric part of a matrix A_{ij} : $B_{ij} = A_{ij} - \delta_{ij} \frac{A_{11}+A_{22}+A_{33}}{3}$ where δ_{ij} is 1 if $i = j$ and is 0 otherwise. This measures the size of the deviatoric part of the matrix.

Specially for **-quad4**, **-quad9**, **-hex8** and **-hex27** elements you can set *operat* to **-force** in case *dof* is **-materi_stress**. Then forces and moments are calculated in these isoparametric elements. See also **post_calcul_materi_stress_force_element_group**.

Specially for geotechnics you can set *operat* to **-total_pressure** in case *dof* is **-materi_stress**. Then the total stress is calculated from the effective stress and the groundflow total pressure. This option is not valid in combination with undrained pressures as obtained by **group_materi_undrained_capacity**.

Specially for geotechnics you can set *operat* to **-static_pressure** in case *dof* is **-groundflow_pressure**. Then the static pressure is calculated.

Specially for geotechnics you can set *operat* to **-dynamic_pressure** in case *dof* is **-groundflow_pressure**. Then the dynamic pressure is calculated.

Specially for geotechnics you can set *operat* to **-k0** in case *dof* is **-materi_stress**. Then the ratio of horizontal and vertical stresses is calculated. If 2D this is the ratio $0.5 \frac{\sigma_{xx} + \sigma_{zz}}{\sigma_{yy}}$. If 3D this is the ratio $0.5 \frac{\sigma_{xx} + \sigma_{yy}}{\sigma_{zz}}$.

Specially for geotechnics you can set *operat* to **-young_apparent** in case *dof* is **-materi_stress**. Then the apparant Young modulus is calculated from the incremental strains and incremental stresses. If the incremental strains are very small so that they do not contain enough information, the total strains and total stresses will be used instead.

Specially for geotechnics you can set *operat* to **-poisson_apparent** in case *dof* is **-materi_stress**. Then the apparent Poisson ratio is calculated from the incremental strains and incremental stresses. If the incremental strains are very small so that they do not contain enough information, the total strains and total stresses will be used instead.

Specially for geotechnics you can set *operat* to **-total_pressure** in case *dof* is **-groundflow_pressure**. Then the total pressure is calculated.

Specially for geotechnics you can set *operat* to **-safety_lifting** in case *dof* is **-materi_stress**. Then the hydraulic safety factor $\frac{\sigma_{vertical} + p_{total}}{p_{total}}$ is calculated. In 1D $\sigma_{vertical} = \sigma_{xx}$, in 2D $\sigma_{vertical} = \sigma_{yy}$ and in 3D $\sigma_{vertical} = \sigma_{zz}$.

Specially for geotechnics you can set *operat* to **-safety_piping** in case *dof* is **-materi_stress**. Then the hydraulic safety factor $\frac{\sigma_{vertical} + p_{dynamic}}{p_{dynamic}}$ is calculated.

The next piece of input file

```
...
materi_stress
```

```

materi_strain_plasti
end_initia
...
post_calcul -materi_stress -size_dev -materi_strain_plasti -size_tot
...
control_timestep 1 ...
control_print 1 -node_dof_calcul

```

will print records like

```
node_dof_calcul index 0.2 1.1e-4
```

Here the 0.2 is the equivalent Von Mises stress and *1.1e-4* measures the plastic strain matrix.

See also **post_calcul_absolute** and **post_calcul_label**.

7.794 **post_calcul_absolute** *switch*

If *switch* is set to **-yes** all results of **post_calcul** are set to be positive values. This may be done if you prefer positive values in your presentation of results.

7.795 **post_calcul_label** *doflabel_0 label_1 ...*

This record will be filled with the names of the data that is calculated by means of the **post_calcul** option. The first name comes from the first *dofoperat* in **post_calcul**, the second name comes from the second *dofoperat* in **post_calcul**, etc. You can find this record in the dbs file after a calculation.

7.796 **post_calcul_limit** *lower_0 upper_0 lower_1 upper_1 ...*

With this record you can specify the lower and upper allowed values for all calculated results. With *lower_dof_0* you specify the lower allowed value for the first result. With *upper_dof_0* you specify the upper allowed value for the first result. Etc.

7.797 **post_calcul_materi_stress_force_average** *switch*

See first **post_calcul_materi_stress_force_element_group**.

This **post_calcul_materi_stress_force_average** option is only available for **quad9** and **hex27** elements. It can be used if forces and moments are primarily calculated in two opposing end faces of the **quad9** and **hex27** element. If *switch* set to **-yes**, the forces and moments of nodes in the plane between the two end faces will be set to the averaged values from the forces and moments on the two opposing end faces. If *switch* set to **-no** this is not done. Default *switch* is **-yes**.

7.798 **post_calcul_materi_stress_force_direction_exclude** *dir_x dir_y dir_z*

See first **post_calcul_materi_stress_force_element_group**.

In 3D, Tochnog needs to know for which element sides it should determine forces and moments. For this purpose you need to specify this direction *dir_x dir_y dir_z*. All element sides with normals in this direction will be neglected; no forces and moments will be determined for such sides.

Typically, in a tunnel calculation you take the tunnel length direction as *dir_x dir_y dir_z*.

7.799 **post_calcul_materi_stress_force_direction_exclude_epsilon** *eps*

With *eps* you can influence which normals are considered to be in the specified exclude direction. A small *eps* specifies that only very precise normals in the specified direction will be excluded. A large *eps* specifies that also not precise normals in the specified direction will be excluded. In fact *eps* is the difference from inproduct between the specified exclude direction with the normal direction and 1. Default *eps* is $1.e - 8$.

7.800 **post_calcul_materi_stress_force_direction_include** *dir_x dir_y dir_z*

See first **post_calcul_materi_stress_force_element_group**.

In 3D, Tochnog needs to know for which element sides it should determine forces and moments. For this purpose you need to specify this direction *dir_x dir_y dir_z*. All element sides with normals perpendicular to this direction will be neglected; no forces and moments will be determined for such sides.

Typically, in a sheet pile calculation you take the sheet pile height direction as *dir_x dir_y dir_z*.

7.801 **post_calcul_materi_stress_force_direction_include_epsilon** *eps*

With *eps* you can influence which normals are considered to be perpendicular to the specified include direction. A small *eps* specifies that only normals precisely perpendicular to the specified direction will be excluded. A large *eps* specifies that also normals not precisely perpendicular to the specified direction will be excluded. In fact *eps* is the difference from inproduct between the specified include direction with the normal direction and 0. Default *eps* is $1.e - 8$.

7.802 **post_calcul_materi_stress_force_element_group** *element_group_0 element_group_1* ...

With the **post_calcul -mater_i_stress -force** option the normal force, shear force and moment(s) are calculated for the isoparametric elements **-quad4**, **-quad9**, **-hex8** and **-hex27**. This option is meant for structures like sheet piles, tunnel shells, etc. where there is only 1 element over the thickness of the structure. Thus the element has a thickness equal to the complete thickness of the structure, and the length of the element is a part of the total length of the structure (e.g. tunnel length).

In the following definitions of forces and moments, *n* denotes the normal to an element side, *t* denotes the thickness direction in the side, and *l* denotes the length direction. The 2D and 3D normal force **nor** results is defined by the normal stresses σ_{nn} integrated over the thickness. The 2D and 3D shear force **she** results is defined by the shear stresses σ_{nt} integrated over the thickness. The 2D moment **mom** and 3D moment **mom1** are defined by the moment contributions of normal stresses σ_{nn} with a distance in thickness direction d_t relative to the middle of the element, integrated over thickness direction (radial bending moment in tunnel shell, thickness

bending moment in sheet pile, etc.). The 3D moment **mom2** is defined by the moment contributions of normal stresses σ_{nn} with a distance in length direction d_l relative to the middle of the element, integrated over thickness direction (bending moment in tunnels, sheet piles, etc.).

The forces and moments will be calculated per unit length l of the isoparametric element, where l is the size of the element in length direction. In a 3D calculation, the length of an element is determined from the nodal coordinates differences in length direction. In a axis-symmetric 2D calculation, the length of the elements is set to $2 * \text{PI} * \text{radius}$ by Tochnog (notice that with this definition values cannot be calculated at the symmetry axis with zero radius). In a plane 2D calculation, the length of the elements is set to 1 by Tochnog.

The normal force and moment(s) are given the proper sign (plus or minus). For example, a positive normal force means that the structure is under tension. For the shear force, however, always a positive value is calculated by Tochnog, so only the size of the shear force is available (and not the direction of the shear force).

For all of the forces and moment vectors, we want to display the vector in thickness direction of the structure, to get a clear view in postprocessors (e.g. GID). Thus, the components in global x- and y-direction are determined such that the vector direction is in thickness direction of the structure. Because of this, the components by themselves are not the real physical components of the force or moment; they are only convenient values for getting clear plots in postprocessors. However, the size of the vector formed by these components (square root of components squared), indeed is the real physical size of the force or moment, so the size can indeed be used for design purposes. For your convenience, the size of each vector is also calculated automatically by Tochnog. For example, for the normal forces Tochnog calculates **-nors_sig**, **-nory_sig** and **-norx_sig** which are the global plot vector x-component, y-component and the physical real size respectively.

To enable a correct force or moment direction in either the positive or negative thickness direction, Tochnog wants you to specify **post_calcul_materi_stress_force_reference_point**.

In 3D, you need to specify either **post_calcul_materi_stress_force_direction_exclude** or **post_calcul_materi_stress_force_direction_include**. With these records you can determine for which element sides forces and moments should be determined. The direction and element should be such that for each element for which you want to determine forces and moments exactly 4 sides should be consistent with the specified direction. Otherwise the present option for determination of forces and moments is not available for the element. Only one of **post_calcul_materi_stress_force_direction_exclude** and **post_calcul_materi_stress_force_direction_include** should be specified, not both.

The *element_group_0 element_group_1 ...* of this **post_calcul_materi_stress_force_element_group** specify the groups of isoparametric elements for which the forces and moments should be determined by Tochnog.

Summary of conditions for the **post_calcul -materi_stress -force** option to work well:

- Only 1 element in thickness direction.
- Elements in 3D should be regular shaped in length direction. That is, the element sides perpendicular to the length direction should be completely parallel.
- At least 1 timestep should be done (since element forces needed for this option are setup in a timestep)

7.803 **post_calcul_materi_stress_force_reference_point** *x_0 y_0 z_0 x_1 y_1 z_1 ...*

See first **post_calcul_materi_stress_force_element_group**.

For example tunnels typically are of circular or piecewise circular geometry. To get a correct direction of the calculated forces and moments, Tochnog needs to know the approximate middle point of the tunnel, so that it can put all negative forces and moments and positive forces and moments consistently outwards or inwards in thickness direction of the structure. Thus, you need to specify with this **post_calcul_materi_stress_force_reference_point** record the approximate middle point of the tunnel that you are evaluating for each of the element groups. In case you have a sheet pile, you should specify a reference point on a large perpendicular distance away from the sheet pile.

You need to specify a reference point for each element group specified in **post_calcul_materi_stress_force_element_group**.

In 3D you need to specify the x, y and z value for each reference point. In 2D you only need to specify the x and y value for each reference point.

See also **post_calcul_materi_stress_force_plot_switch**.

7.804 **post_calcul_materi_stress_force_outer** *switch*

If *switch* is set to **-yes**, the forces and moments are only calculated for the nodes at the outer sides of the elements; these are the nodes which have the furthest distance relative to the reference point. This will give a bit more nice vector plots.

Default, if **post_calcul_materi_stress_force_outer** is not specified, *switch* is set to **-no**. This will give a bit more nice contour fill plots.

7.805 **post_calcul_materi_stress_force_plot_switch** *switch_0 switch_1 ...*

If you don't like the direction in which tochnog draws the vectors (outward or inward), you can switch the direction by setting the corresponding switch to **-yes**. In 2D you need to specify a switch for the normal force, shear force and moment. In 3D you need to specify a switch for the normal force, shear force and two moments.

7.806 **post_calcul_materi_stress_force_thickness_switch** *switch_element_group_0 switch_element_group_1 ...*

See first **post_calcul_materi_stress_force_element_group**.

In 3D Tochnog normally assumes that the shortest element direction in the side where forces and moments are calculated is the structure thickness direction. If that is not the case, e.g. if you have very short elements in a tunnel length direction, then you need to explain Tochnog that it should switch to the longest element direction as structural thickness direction, by setting a to **-yes**.

This ensures that the shear force is always really calculated over the structural thickness, and the first moment is really the moment over the structural thickness.

If you specify **post_calcul_materi_stress_force_thickness_switch** you need to give a switch for each element group of **post_calcul_materi_stress_force_element_group**.

7.807 **post_calcul_multiply** *factor_0 factor_1 ...*

With this record you can specify a multiplication factor for each calculated item. This comes handy when you prefer another definition. If you specify **post_calcul_multiply**, you need to give a factor for each item.

7.808 **post_calcul_static_pressure_height** *coord_min,0 coord_max,0 height_ref,0 coord_min,1 coord_max,1 height_ref,1 ...*

Using this option the static pressure as required by **post_calcul-groundflow_pressure-static_pressure** is determined relative to the reference height, and not anymore to a groundwater level. Thus, the Δz in the equation for $p_{\text{static}} = \rho g \Delta z$ is taken relative to the specified reference height in this **post_calcul_static_pressure_height** record.

You can specify multiple regions. The first region is between vertical coordinate *coord_min,0* and *coord_max,0*. The *coord_min,0* and *coord_max,0* themselves are included as part the region. If a node is inside this region the *height_ref,0* is used as phreatic level height in the equation for the static pressure. The second region is between vertical coordinate *coord_min,1* and *coord_max,1*. The *coord_min,1* and *coord_max,1* themselves are included as part the region. If a node is inside this region the *height_ref,1* is used as phreatic level height in the equation for the static pressure.

If a node is not inside any of the regions, and if the groundflow phreatic level itself is not specified, the static pressure cannot be determined and remains zero.

7.809 **post_count** *dataitem_name_0 dataitem_name_1 ...*

With this **post_count** record you can specify data items for which the number of active indices should be counted. The results will be placed in the record **post_count_result**.

For example count the number of active elements, nodes and geometry points by:

```
...  
post_count -element -node -geometry_point ...
```

7.810 **post_data** *index dataitem_name_0 dataitem_index_0 dataitem_number_0 dataitem_name_1 dataitem_index_1 dataitem_number_1 ...*

The specified data items are taken, and each is multiplied with its corresponding factor in **post_data_factor** and added to **post_data_result**. This allows you to conveniently follow the sum of data item, each multiplied with some factor.

7.811 **post_data_factor** *index factor_0 factor_1 ...*

See **post_data**.

7.812 **post_data_result** *index result*

See **post_data**.

7.813 **post_element_force** *index dir_normal_x dir_normal_y dir_normal_z dir_shear0_x dir_shear0_y dir_shear0_z dir_shear1_x dir_shear1_y dir_shear1_z middle_x middle_y middle_z*

With this record you can calculate the normal force, shear force and moments in cross sections. Only cross sections at the side of elements are allowed; so that typically is the common side between two elements, or the side at the edge of a domain; a cross section through the interior of elements is not allowed. Below we will describe how you can select elements. For the combination of selected elements nodal forces will be used to determine cross section forces and moments. The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are summed to give a normal force *normal_force*. The nodal force components in the *dir_shear0_x dir_shear0_y dir_shear0_z* direction are summed to give the first shear force *shear0_force*. The nodal force components in the *dir_shear1_x dir_shear1_y dir_shear1_z* direction are summed to give the second shear force *shear1_force*. The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are multiplied with the distance in *dir_shear0_x dir_shear0_y dir_shear0_z* direction as measured from the *middle_x middle_y middle_z* vector, and this is summed to give the first bending moment *moment0*. The nodal force components in the *dir_normal_x dir_normal_y dir_normal_z* direction are multiplied with the distance in *dir_shear1_x dir_shear1_y dir_shear1_z* direction as measured from the *dir_shear0_x dir_shear0_y dir_shear0_z* vector, and this is summed to give the first bending moment *moment1*. The results for the normal force, two shear forces and two moments will be placed in the record **post_element_force_result**.

In 3D you need to specify the complete **post_element_force** record and you get the normal force, two shear forces and two bending moments in the **post_element_force_result** record. The directions *dir_shear0_x dir_shear0_y dir_shear0_z* and *dir_shear1_x dir_shear1_y dir_shear1_z* should be perpendicular.

In 2D you need to specify only a partial record **post_element_force** as *index dir_normal_x dir_normal_y dir_shear0_x dir_shear0_y middle_x middle_y* and you get the normal force, one shear force and one bending moment in the **post_element_force_result** record.

In 1D you need to specify only a partial record **post_element_force** as *index dir_normal_x middle_x* and you get the normal force in the **post_element_force_result** record.

You can restrict with **post_element_force_geometry** with the same index that the **post_element_force** is only evaluated for nodes on a specific geometry.

You can restrict with **post_element_force_group** with the same index that the **post_element_force** is only evaluated for certain element groups.

You can restrict with **post_element_force_number** with the same index that the **post_element_force** is only evaluated for certain element numbers.

You can restrict with **post_element_force_normal** with the same index that the **post_element_force** is only evaluated for elements in positive normal direction *dir_normal_x dir_normal_y dir_normal_z*. If you don't specify **post_element_force_normal** elements on both sides will be used if present.

You can require by setting the *switch* in **post_element_force_force** with the same index that also the external forces (like gravity and edge loads etc.) are added to the result.

You can require by setting the *switch* in **post_element_force_inertia** with the same index that also the inertia forces is added to the result.

If you are not happy with the sign or units with which the forces are calculated, you can use a multiply factor in **post_element_force_multiply_factor** with the same index to get what you want.

Please realise that in calculation with groundwater the calculated forces contain the force due to effective stresses and also due to groundwater total pressure (pore pressure).

We now give some examples for a 2D vertical pile driven into the soil in a dynamic **inertia ...** calculation, and including gravity **force_gravity ...** and an external force **force_element_edge ...** at the top of the pile. Below *x_pile* is the x-coordinate at the middle of the pile, *y_pile.middle* is the y-coordinate at the middle of the pile, *y_pile.bottom* is the y-coordinate at the bottom of the pile and *pile_group* is the group number of the pile.

The force in a cross section (force resulting from normal stress in cross section):

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile
post_element_force_geometry 10 -pile_cross_section
post_element_force_group 10 pile_group
...
...
```

Here *pile_cross_section* is a geometry line through the cross section of the pile,

The force along the shaft (force resulting from shear stress along shaft):

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile.bottom
post_element_force_geometry 10 -pile_shaft
post_element_force_group 10 pile_group
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...
```

Here *pile_shaft* is a geometry line containing only nodes of the pile shaft,

The force at the pile toe (force resulting from normal stress at pile tip):

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile.bottom
post_element_force_geometry 10 -pile_toe
post_element_force_group 10 pile_group
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...
```

Here *pile_toe* is a geometry line containing only nodes of the pile toe,

The complete force on the pile:

```
...
post_element_force 10 0. 1. 1. 0. x_pile y_pile_bottom
post_element_force_geometry 10 -pile_complete
post_element_force_group 10 pile_group
post_element_force_force 10 -yes
post_element_force_inertia 10 -yes
...
...
```

Here *pile_complete* is a geometry line containing all nodes of the pile,

Also see the example calculation **force14.dat** and **force17.dat**.

7.814 **post_element_force_force** *index switch*

See **post_element_force**.

7.815 **post_element_force_geometry** *index geometry_item_name geometry_item_index*

See **post_element_force**.

7.816 **post_element_force_group** *index element_group_0 element_group_1 ...*

See **post_element_force**.

7.817 **post_element_force_inertia** *index switch*

See **post_element_force**.

7.818 **post_element_force_multiply_factor** *index multiply_factor*

See **post_element_force**.

7.819 **post_element_force_normal** *index switch*

Set *switch* to **-yes** if you want to select elements in positive normal direction. See **post_element_force**.

7.820 **post_element_force_number** *index number_0 number_1 ...*

See **post_element_force**.

7.821 post_element_force_result *index normal_force shear0_force shear1_force moment0 moment1*

See **post_element_force**.

7.822 post_integrate *index data_item_name data_item_index data_item_number ...*

Here you can specify results that should be integrated over time. The integrated results will be placed in the **post_integrate_result** record with the same index.

An example looks like:

```
...
groundflow_pressure
groundflow_velocity
end_initia
...
post_node 1 -average -geometry_line 4
...
post_integrate 3 -post_node_result 1 -gvely
...
...
```

Here the **post_node** record first takes care that the average groundflow y-velocity at nodes on a line are determined, among other dof's. The **post_integrate** record integrates that average groundflow y-velocity over time. In this way the total groundflow debit volume over a line is registered.

7.823 post_global *switch*

With this **post_global** you can ask for global information to be determined if you set *switch* to **-yes**. The following information will then be determined:

- **-post_bounda_force_summed** (total force following from **-bounda_force** records, number of principal dofvalues)
- **-post_element_mass_summed** (total global mass)
- **-post_element_summed** (total number of elements)
- **-post_element_volume_summed** (total global volume without empty elements)
- **-post_element_volume_summed_all** (total global volume with empty elements)
- **-post_materi_inertia_summed** (sum of material nodal inertia, so of **node_inertia**)
- **-post_slide_force_summed** (sum of slide forces in global axes, so of **node_slide_force**)
- **-post_node_summed** (total number of nodes)
- **-post_node_dof_average** (average values for dof's)

- **-post_node_dof_maximum** (maximum values for dof's)
- **-post_node_dof_minimum** (minimum values for dof's)
- **-post_force_edge_summed** (total force following from **-force_edge** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_force_edge_normal_summed** (total force following from **-force_edge_normal** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_force_edge_projected_summed** (total force following from **-force_edge_projected** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_support_edge_normal** (total force following from **-support_edge_normal** integrated over edges in x,y,z directions, *number_of_space_dimensions* values)
- **-post_solver_diagonal_minimum_value** (minimum diagonal term total matrix, only for pardiso solver)
- **-post_solver_diagonal_minimum_node** (node number at which the minimum value is found)
- **-post_solver_diagonal_maximum_value** (maximum diagonal term total matrix, only for pardiso solver)
- **-post_solver_diagonal_maximum_node** (node number at which the maximum value is found)
- **-post_solver_diagonal_ratio** (ratio maximum/minimum diagonal terms total matrix, only for pardiso solver)
- **-post_solver_iterations** (total number of iterations of iterative linear equation solver, only for bicg solver)

If you set *switch* to **-no** then the information will not be determined (this saves a little bit of computer time). Default, if **post_global** is not specified, *switch* to **-yes**.

7.824 **post_integrate_result** *index result*

See **post_integrate**.

7.825 **post_line** *index x_0 y_0 z_0 x_1 y_1 z_1*

This record specifies a line in space for which the average or sum of the dof values will be calculated. The values are placed in a record **post_line_dof** with the same *index*. Internally in TOCHNOG, **post_point** records are used to evaluate the dof's on the line. In 1D only *x_0* and *x_1* should be specified, etc.. In the example below, the average of the *x*-velocity between the points (3,1) and (3,7) will be printed

```
...
number_of_space_dimensions 2
materi_velocity
...
end_data
...
```

```

post_line 1 3. 1. 3. 7.
...
print_filter 0 -post_line_dof 1 -velx
...
control_timestep 1 1. 100.
control_print 1 -post_line_dof

```

The coordinates are defined in the initial mesh. See also: **post_line_n** and **post_line_operat**.

7.826 **post_line_operat** *index operat*

If *operat* is set to **-average** then the average is calculated for the **post_line** record with the same index. If *operat* is set to **-sum** then the sum is calculated for the **post_line** record with the same index.

If this **post_line_operat** is not specified, then *operat* is set to **-average**.

7.827 **post_line_dof** *index dof_0 dof_1 ...*

Average dofvalues at a selected line. See **post_line**.

7.828 **post_line_dof_calcul** ...

See **post_calcul**.

7.829 **post_line_n** *index n*

Use *n* **post_point** records to evaluate the dof's along the line. Default *n* is 5. See **post_line**.

7.830 **post_node** *index data_item operat geometry_entity_name geometry_entity_index*

If *operat* is set to **-sum**, results for the nodal *data_item* are summed. If *operat* is set to **-average**, results for the nodal *data_item* are averaged. For example, you can take for *data_item* the **-node_rhside** data item. In this way you can sum the external nodal forces on a part of the domain.

This operation is done for nodes which are placed on the geometrical entity *geometry_entity_name* *geometry_entity_index*. Instead of a geometrical entity you can also use **-all** to tell that all nodes should be used. Instead of a geometrical entity you can also use **-ra .. -ra** to tell that the nodes of the range should be used.

The result of this **post_node** record is put into the **post_node_result** record (with the same *index*).

7.831 **post_node_factor** *index factor*

You can multiply the result of **-post_node** with *factor*. Default, if **post_node_factor** is not specified, we take *factor* equal to 1.

7.832 **post_node_result** *index result_0 result_1 ...*

See **post_node**.

7.833 **post_node_rhside_fixed** *value_0 value_1 ...*

This record will be filled with the average of the absolute values of **node_rhside** for those dof's which are prescribed (eg with a **bounda_dof**). By example, in a calculation with only velocities (displacements) as primary dof's, this record contains the average of the absolute values of the components of the external forces at the nodes in which the velocity is prescribed. By example, in a calculation with only temperature as primary dof, this record contains the average of the absolute values of the external flux in the nodes in which the temperature is prescribed. Values are only filled for principal dof's (materi velocity, groundflow pressure, condif temperature, ...).

For materi velocities the external forces from **force_edge*_summed**, **force_gravity_summed**, **force_volume_summed**, and **bounda_force_summed** are added to **post_node_rhside_fixed**.

7.834 **post_node_rhside_free** *value_0 value_1 ...*

Same as **post_node_rhside_fixed**, now for free values however. By example, in a calculation with only velocities (displacements) as primary dof's, this record contains the average of the absolute values of the components of the unbalance forces at the nodes in which the velocity is free. By example, in a calculation with only temperature as primary dof, this record contains the average of the absolute values of the unbalance flux in the nodes in which the temperature is free. Values are only filled for principal dof's (materi velocity, groundflow pressure, condif temperature, ...).

7.835 **post_node_rhside_ratio** *ratio*

This record gives during a calculation a measure for the inaccuracy of the calculation. For each primary doctype the ratio between the size of the corresponding parts in **post_node_rhside_fixed** and **post_node_rhside_free** is determined; where for vectors like velocities the vector size is taken, and for scalars like temperature the scalar value:

$$\text{post_node_rhside_ratio} = \frac{\text{post_node_rhside_free}}{\text{post_node_rhside_fixed}}$$

If the size **post_node_rhside_fixed** is below 1.e-10 the *ratio* is directly filled with **post_node_rhside_free**. See also **post_node_rhside_ratio_dof_type**.

7.836 **post_node_rhside_ratio_dof_type** *dof_type_0 ...*

With this option you can specify a list of doctypes which should be used in the calculation of the **post_node_rhside_ratio** result. For example, if both **groundflow_pressure** and **con-**

dif.temperature are initialised, then you can use only the groundflow pressure in the accuracy ratio determination by specifying **post_node_rhside_ratio_dof_type -groundflow_pressure**.

If **post_node_rhside_ratio_dof_type** is not specified and **materi_velocity** is initialised then automatically **post_node_rhside_ratio_dof_type -materi_velocity** will be used.

7.837 **post_node_rhside_ratio_method** *method*

By setting *method* to **-post_node_rhside_free** the *ratio* is directly filled with **post_node_rhside_free**. Default, when this **post_node_rhside_ratio_method** record is not specified, the default definition as specified in **post_node_rhside_ratio** is used,

7.838 **post_point** *index x y z*

This record specifies a point in space for which dofvalues will be calculated. The values are placed in a record **post_point_dof** with the same *index*. The values are obtained by determining in which element the point is located and then using the element's interpolation functions. In 1D only *x* should be specified, etc.. The coordinates are defined in the initial mesh.

7.839 **post_point_dof** *index dof_0 dof_1 ...*

Unknown values at a selected point. See **post_point**.

7.840 **post_point_dof_calcul** ...

See **post_calcul**.

7.841 **post_quadrilateral** *index x_0 y_0 z_0 x_1 y_1 z_1 x_2 y_2 z_2 x_3 y_3 z_3*

This record specifies a quadrilateral in space for which the average of the dof values will be calculated. The values are placed in a record **post_quadrilateral_dof** with the same *index*. Internally in TOCHNOG, **post_point** records are used to evaluate the dof's on the quadrilateral. In 2D only *x_0 y_0*, *x_1 y_1*, etc. should be specified. The coordinates are defined in the initial mesh. See also: **post_quadrilateral_n**.

7.842 **post_point_eps_iso** *index eps*

Tolerance with which a **post_point** is accepted to be part of an element. The default value is 1.e-3. You can increase the default value if a **post_point** is exactly on or over the border of the mesh, so that the **post_point** may be not found; typically try 0.1 or so.

7.843 **post_quadrilateral_dof** *index dof_0 dof_1 ...*

Average dofvalues at a selected quadrilateral. See **post_quadrilateral**.

7.844 **post_quadilateral_dof_calcul** ...

See **post_calcul**.

7.845 **post_quadilateral_n** *index n*

Use *n* **post_point** records in each direction to evaluate the dof's along the quadrilateral. Default *n* is 5. See **post_quadilateral**.

7.846 **post_strain_volume_absolute** *index volume_increase_absolute*

This record will hold after the calculation the absolute volume increase summed over the elements that are selected in the **strain_volume_element**, **strain_volume_element_group** and **strain_volume_geometry** records (with the same index).

The actual volume increase which you will find in this **post_strain_volume_absolute** record will depend on the relative volume strain or absolute volume increase that you specified, but also on stiffnesses of neighboring zones, boundary conditions, etc.

You can use this **post_strain_volume_absolute** result to decide to manually change the specified relative volume strain or absolute volume increase and rerun the calculation.

7.847 **post_strain_volume_initial** *index volume_initial*

Initial volume of selected elements.

7.848 **post_strain_volume_relative** *index volume_strain_relative*

Relative volume strain percentage. Otherwise the same as **post_strain_volume_absolute**.

7.849 **print_apply** *switch*

If *switch* is set to **-no**, then all **control_print_*** records will not be applied. Default, if **print_apply** is not specified, *switch* is set to **-yes**.

7.850 **print_arithmetic** *switch*

If *switch* is set to **-yes**, all evaluated arithmetics will be printed. See the start of the data part for an explanation about arithmetics. The printing will be done to the file **tochnog_arithmetic.txt**.

7.851 **print_control** *switch*

If *switch* is set to **-yes**, the control index being evaluated will be printed. Handy for keeping track on what the program is doing.

7.852 `print_data_name` *switch*

If *switch* is set to **-yes**, all possible data names will be printed. The printing will be done to the file **tochnog_data_name.txt**.

This is convenient to search in the **tochnog_data_name.txt** file fast for options. By example under linux to search all options which have the word **group** in it do **grep group tochnog_data_name.txt**.

7.853 `print_database_calculation` *switch*

If *switch* is set to **-yes**, the database will be written after successful completion of a calculation to the file **name.dbs**, where *name* is the name of the input file. If *switch* is set to **-no**, the database will not be written.

Default, *switch* is set to **-yes**.

7.854 `print_define` *switch*

If *switch* is set to **-yes**, all evaluated defines will be printed. See the start of the data part for an explanation about defines. The printing will be done to the file **tochnog_define.txt**.

7.855 `print_element_geometry_present` *switch*

See **element_geometry_present**. Default *switch* is set to **-no**.

7.856 `print_failure` *switch*

If *switch* is set to **-yes** then failure of elements due to one of the failure criteria (**group_materi_failure_rupture** etc.) will be reported.

7.857 `print_filter` *index data_item_name data_item_index number_0 number_1 ...*

The data selected in the records **control_print**, **control_print_dof**, **control_print_dof_rhside** and **control_print_element** will be filtered at output. Thus only a limited amount of data will actually be printed. Here *data_item_name* is the name of the data item to be filtered, e.g. *data_item_name* is **-node_dof**. *data_item_index* is the index of the *data_item_name* record which passes the filter. If, for example, *data_item_index* is 3 then only index 3 passes the filter. If *data_item_index* is **-all** then all indices pass the filter. If, for example, *data_item_index* is **-geometry_line 3** (valid if *data_item_name* is **-node** or another nodal item) then only records with coordinates located on line 3 pass the filter. If, for example, *data_item_index* is **-geometry_line 3** (valid if *data_item_name* is **-element** or another element item) then only element with at least one coordinate located on line 3 pass the filter. If, for example, *data_item_index* is **-ra ... -ra** then indices in this range pass the filter. If, for example, *data_item_index* is **-macro 4** and *data_item_name* is data valid at a node (or element), then only nodes (or elements) generated by the macro number 4 pass the filter (see **control_mesh_macro_*** for macro's). If, for example, *data_item_index* is **-macro -none** and *data_item_name* is data valid at a node (or element) then only nodes (or elements) not generated by any macro pass the filter (see **control_mesh_macro_*** for macro's).

For example, if *number_0* is 3 then the fourth value of a record passes the filter. If *number_0* is **-all** the whole record passes the filter. If, for example, *number_0* is **-velx** while *data_item_name* is **-node_dof** then only *x*-velocities pass the filter.

Some examples are

```
print_filter 1 -node_dof -all -temp -sigxx (temperatures and xx-stresses)
print_filter 2 -node -geometry_line 3 0 (x-coordinates on line 3)
```

With **control_print_filter** you can select if the records **control_print**, **control_print_dof** or **control_print_dof_rhside** (with the same index) should use specific filters (specify the indices of the filter for *print_filter_index*), should use all filters (specify **-all** for *print_filter_index*), or should use no filter at all (specify **-none** for *print_filter_index*). Default, if **control_print_filter** is not specified, all filters will be used for a print option.

Example:

```
print_filter 1 -node_dof ...
print_filter 2 -node_dof_all ...
print_filter 3 ...
...
control_print_dof 10 ...
control_print_filter 10 1 2 (only use filter 1 and 2)
...
control_timestep 20 ...
control_print 20 ...
control_print_filter 20 -all (use all filters)
```

All used filters are placed in-line for a data item; thus only data which passes all used filters for that data item will be printed.

7.858 print_gid_calculation *switch*

If you set *switch* to **-yes** the gid files will be printed at the end of the calculation. If you set *switch* to **-no** the gid files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

7.859 print_gid_contact_spring2 *number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **contact_spring2** with two nodes, and to 1 if you want to draw **contact_spring2** with one node. Default, if **print_gid_contact_spring2** is not specified, then 1 is used for *number_of_nodes*.

7.860 print_gid_coord *switch*

If *switch* is set to **-yes** the coordinates of nodes is plotted in gid.

7.861 `print_gid_mesh_activate_gravity` *switch*

See also `mesh_activate_gravity_time`.

7.862 `print_gid_old` *switch*

If *switch* is set to **-yes** prism's will be plotted as tet's in GID. If *switch* is set to **-no** prism's will be plotted as Prime's in GID when possible. Default, if *switch* is not specified, *switch* is set to **-no**.

7.863 `print_gid_spring2` *number_of_nodes*

Set *number_of_nodes* to 2 if you want to draw **spring2** with two nodes, and to 1 if you want to draw **spring2** with one node. Default, if `print_gid_spring2` is not specified, then 1 is used for *number_of_nodes*.

7.864 `print_group_data` *dataitem_name_0 dataitem_name_1 ...*

Print in the gid files **group_*** data items for isoparametric finite elements. As a typical example use **-group_materi_elasti_young**; then you get in the gid plot what the young model distribution is for isoparametric finite elements in the mesh.

All group data is averaged over each element, so you will see a constant value per element (even when the group data item may vary over the different integration points in an element).

For elements which do not have a specific group data item a value 0 will be plotted. Tochnog sets the gid group data information in the timesteps, so only after timesteps have been taken you will see meaningful results for the group data in gid plots.

The values will also be placed in the **element_print_group_data** records.

7.865 `print_gmsh_calculation` *switch*

If you set *switch* to **-yes** the gmsh files will be printed at the end of the calculation. If you set *switch* to **-no** the gmsh files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-no**.

7.866 `print_gmsh_dummy` *switch*

See `control_print_gmsh_dummy`. This `print_gmsh_dummy` holds for all gmsh printing, unless it is overruled by a `control_print_gmsh_dummy`.

7.867 `print_mesh_dof` *dof_0 dof_1 ...*

This option allows you to print results for dof's (temperatures, groundflow pressures, ...) in a first calculation and use these results later in a second calculation as boundary conditions. This comes handy when you need to run the second calculation multiple times, and the results for the printed dof's can be taken from the first calculation. In this way, the computing time of the second

calculation can be smaller, and also a different FE mesh can be used in the first calculation and the second calculation for the different doffields.

In the first calculation you can print the dof's with the command **print_mesh_dof**; the results will be printed in the file **print_mesh_dof.txt**. The *dof_0 dof_1 ...* of **print_mesh_dof** specify the dof's which will be printed. In the first calculation printing of the dof's to the file **print_mesh_dof.txt** will actually be done for when *switch* is set to **-yes** in **control_print_mesh_dof**.

For the second calculation rename the file **print_mesh_dof.txt** into **bounda_mesh_dof.txt**. You can specify which of the dof's in the file **bounda_mesh_dof.txt** will actually be used a prescribed value ('boundary condition') with the *dof_0 dof_1 ...* of **bounda_print_mesh_dof**. You can restrict the nodes to which this will be done by **bounda_print_mesh_dof_geometry** (please realise using a geometry point with a very large tolerance in combination with **geometry_element_group** you can effectively select the geometry formed by an element group).

The FE meshes as used in the first calculation and in the second calculation need not be the same, and are also allowed to vary in time (in building processes, excavations, etc.). Nodes from the second mesh will be located in the first mesh, and doffields will be interpolated from the first mesh to the second mesh. In case a node from the second mesh is not inside any isoparametric element of the first mesh, the value for the dof's as specified in the optional **bounda_print_mesh_dof_values** will be used. In **bounda_print_mesh_dof_values** you need to specify values for each and every dof that was specified with **print_mesh_dof** in the first calculation. If the node of the second mesh cannot be found in the first mesh and also **bounda_print_mesh_dof_values** is not specified then the dof's will be taken from the closest node of the first mesh.

Results for the second mesh will be linearly interpolated in time from results of the first mesh.

Example first calculation in which only a temperature field is calculated:

```
echo -yes
number_of_space_dimensions 2
condif_temperature
end_initia
...
print_mesh_dof -temp
...
control_timestep 10 ...
control_print_mesh_dof 10 -yes (print in print_mesh_dof.txt)
...
```

Example second calculation in which the temperature field calculated in the first calculation is imposed:

```
echo -yes
number_of_space_dimensions 2
condif_temperature
materi_velocity
materi_displacement
materi_stress
end_initia
...
bounda_print_mesh_dof -temp
bounda_print_mesh_dof_values 20. (read from bounda_mesh_dof.txt)
```

...

7.868 **print_node_geometry_present** *switch*

See **node_geometry_present**. Default *switch* is set to **-no**.

7.869 **print_precision** *number_of_values*

With *number_of_values* you can set for all printing how many values will be used at printing. For example, setting *number_of_values* to **4** the internal tochnog double **98.123456789** will be printed as **98.12** when using **control_print**, **control_print_gid** etc.

7.870 **print_tecplot_calculation** *switch*

If you set *switch* to **-yes** the tecplot files will be printed at the end of the calculation. If you set *switch* to **-no** the tecplot files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

7.871 **print_vtk_calculation** *switch*

If you set *switch* to **-yes** the vtk files will be printed at the end of the calculation. If you set *switch* to **-no** the vtk files will not be printed at the end of the calculation. Default, if *switch* is not specified, it is set to **-yes**.

7.872 **processors** *nproc*

With this record you can set the number of CPUs you want to use (*nproc*). If your TOCHNOG implementation does not allow for more processors, this record is ignored. In fact, not the number of processors but the number of threads is set (that is, if you use 2 threads while your system only supports 1 processor than those threads are split over that single processor).

Error messages may become confusing when you use more than one processor.

Default *nproc* is 1.

7.873 **processors_maximum** *switch*

If *switch* is set to **-yes**, the **processors** record will be set to the maximum number as allowed by your computer.

Default *switch* is set to **-yes**. This **processors_maximum** record will not be used if the **processors** record is specified.

7.874 **processors_partition** *npartition*

The element loop is paralised as follows. The master process gives away small amounts on the total number of elements to child processes, and if a child process is ready it gets a new small amount of the master process. In fact , a child process gets each time an amount of $\frac{nelement}{npartition*processors}$ where *nelement* is the number of elements, *npartition* is specified in **processors_partition**, and *processors* is specified in **processors**. Default, if **processors_partition** is not specified, we set *npartition* to 1.

7.875 **relaxation** *relax_0 relax_1 ...*

Relaxation parameters for adjusting dof's in iterations. This can stabilize the calculation. For example, a relaxation parameter of 0.1 means that the corresponding dof is now completely updated with the iterative change, but only 10 percent of the change is actually applied in a iteration.

If enough iterations are used, the relaxation parameters will not influence the final solution.

You should specify a relaxation parameter term for each principal dof which is present in the calculation (see the start of the data part description for a list of principal dof's; these are velocities, temperature, etc.).

The relaxation is used for all timesteps. See also **control_relaxation**.

7.876 **repeat_save_result** *index result_0 result_1 ...*

See **control_repeat_save**. The index is the number of repetition (index 0 is repeat 0, index 1 is repeat 1, etc.)

7.877 **repeat_save_calculate_result** *average_0 variance_0 average_1 variance_1 ...*

See **control_repeat_save_calculate**.

7.878 **safety_slip_circle_grid_middle** *index x_first y_first x_last y_last*

This record specifies a grid with middles of a circle for safety factor calculations. With *x_first y_first* you specify the first middle. With *x_last y_last* you specify the last middle. With **safety_slip_circle_grid_middle_n** you specify the number of middles that should be evaluated in the safety calculation; all middles together form an equidistant grid between *x_first y_first* and *x_last y_last*.

As a special option you can only specify *x_first y_first* and not specify **safety_slip_circle_grid_middle_n**; then only one middle *x_first y_first* will be evaluated for the circle in the safety calculation.

See also **control_safety_slip**.

7.879 **safety_slip_circle_grid_middle_n** *index n*

See **safety_slip_circle_grid_middle**.

7.880 **safety_slip_circle_grid_radius** *index r_first r_last*

This record specifies the radius of a circle for safety factor calculations.

With *r_first* you specify the first radius. With *r_last* you specify the last radius. With **safety_slip_circle_grid_radius_n** you specify the number of radius that should be evaluated in the safety calculation; all radius to be evaluated will be put equidistant between *r_first* and *r_last*.

As a special option you can only specify *r_first* and not specify **safety_slip_circle_grid_radius_n**; then only one radius *r_first* will be evaluated for the circle in the safety calculation.

7.881 **safety_slip_circle_grid_radius_n** *index n*

See **safety_slip_circle_grid_radius**.

7.882 **safety_slip_circle_grid_result** *index x y r safety_factor*

This record will after the calculation be filled with the middle, radius and safety factor for the critical surface (for the slip circles with the same index).

7.883 **safety_slip_circle_grid_segment_n** *index n*

With this record you can specify how many segments in the circle will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_circle_grid_segment_n** is not specified, then 90 segments will be used.

7.884 **safety_slip_circle_line_middle** *index x_first y_first x_last y_last*

This record specifies a line with middles of a circle for safety factor calculations. With *x_first y_first* you specify the first middle. With *x_last y_last* you specify the last middle. With **safety_slip_circle_line_middle_n** you specify the number of middles that should be evaluated in the safety calculation; all middles together form an equidistant line between *x_first y_first* and *x_last y_last*.

As a special option you can only specify *x_first y_first* and not specify **safety_slip_circle_line_middle_n**; then only one middle *x_first y_first* will be evaluated for the circle in the safety calculation.

See also **control_safety_slip**.

7.885 **safety_slip_circle_line_middle_n** *index n*

See **safety_slip_circle_line_middle**.

7.886 **safety_slip_circle_line_radius** *index r_first r_last*

This record specifies the radius of a circle for safety factor calculations.

With *r_first* you specify the first radius. With *r_last* you specify the last radius. With **safety_slip_circle_line_radius_n** you specify the number of radius that should be evaluated in the safety calculation; all radius to be evaluated will be put equidistant between *r_first* and *r_last*.

As a special option you can only specify *r_first* and not specify **safety_slip_circle_line_radius_n**; then only one radius *r_first* will be evaluated for the circle in the safety calculation.

7.887 **safety_slip_circle_line_radius_n** *index n*

See **safety_slip_circle_line_radius**.

7.888 **safety_slip_circle_line_result** *index x y r safety_factor*

This record will after the calculation be filled with the middle, radius and safety factor for the critical surface (for the slip circles with the same index).

7.889 **safety_slip_circle_line_segment_n** *index n*

With this record you can specify how many segments in the circle will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_circle_line_segment_n** is not specified, then 90 segments will be used.

7.890 **safety_slip_combined_linear** *index x_first,0 y_first,0 x_first,1 y_first,1 . . . x_last,0 y_last,0 x_last,1 y_last,1 . . .*

This record specifies combined linear lines along which the safety factor should be calculated.

All data with *first* specifies the first combined linear line. The *x_first,0 y_first,0* specifies the first point of the first line piece of the first combined linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the first combined linear line. The *x_first,2 y_first,2* specifies the first point of the second line piece of the first combined linear line, the *x_first,3 y_first,3* specifies the second point of the second line piece of the first combined linear line etc.

All data with *last* specifies the last combined linear line. The *x_last,0 y_last,0* specifies the first point of the first line piece of the last combined linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the last combined linear line. The *x_last,2 y_last,2* specifies the first point of the second line piece of the last combined linear line, the *x_first,3 y_first,3* specifies the second point of the second line piece of the last combined linear line etc. This last combined linear line should have an equal number of points as the first combined linear line.

With **safety_slip_combined_linear_n** you specify the number of combined linear lines that should be evaluated in the safety calculation; all combined linear lines to be evaluated will be put equidistant between the first combined linear line and the second combined linear line.

As a special option you can only specify data for the first combined linear line, and specify not data for the last combined linear line and not **safety_slip_combined_linear_n**; then only one combined linear line will be used.

See also **control_safety_slip**.

7.891 **safety_slip_combined_linear_n** *index n*

See **safety_slip_combined_linear**.

7.892 **safety_slip_combined_linear_result** *index x_0 y_0 x_1 y_1 . . . safety_factor*

This record will after the calculation be filled with the combined linear line for the critical surface (for the combined linear lines circles with the same index).

7.893 **safety_slip_combined_linear_segment_n** *index n*

With this record you can specify how many segments in a line piece of a combined linear line will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_combined_linear_segment_n** is not specified, then 10 segments will be used.

7.894 **safety_slip_ellipsoide** *index middle_x_first middle_y_first middle_z_first base1_x_first base1_y_first base1_z_first base2_x_first base2_y_first base2_z_first a_first b_first c_first middle_x_last middle_y_last middle_z_last base1_x_last base1_y_last base1_z_last base2_x_last base2_y_last base2_z_last a_last b_last c_last*

This record specifies a 3D ellipsoide for which the safety factor should be calculated. The ellipsoide equation is $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$, where x , y and z are local coordinates in the ellipsoide. The ellipsoide is specified by 12 parameters in tochnog.

All parameters with *first* specifies the first ellipsoide. The *middle_x_first middle_y_first middle_z_first* specifies the ellipsoide middle (for which the local coordinates are 0; $x = 0$, $y = 0$, $z = 0$). The *base1_x_first base1_y_first base1_z_first* specifies the direction of the local x axes in space. The *base2_x_first base2_y_first base2_z_first* specifies the direction of the local y axes in space. Tochnog determines automatically the direction of the local z axes in space. The a b c specifies the radii in respective the local x , y and z direction.

All parameters with *last* specifies the last ellipsoide.

With **safety_slip_ellipsoide_n** you specify the number of variations that should be used for each of the specified ellipsoids parameters. All parameters will be interpolated between the values specified for the first and last ellipsoide. In case you want to keep a parameter fixed, thus it should not be varied, simply specify an equal value for the parameter in the first and last ellipsoide.

As a special option you can only specify parameters for the first ellipsoide, and specify not parameters for the last ellipsoide.

See also **control_safety_slip**.

7.895 **safety_slip_ellipsoide_method** *index method*

The normal on the ellipsoide surface is uniquely defined, so that the normal stresses are uniquely defined. The slip direction in the surface is not uniquely defined however. Below several possibilities are listed.

If *method* is set to **-safety_slip_ellipsoide**, then the ellipsoide local x direction will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

If *method* is set to **-materi_displacement** or **-materi_velocity_integrated**, then the last calculated displacements will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

If *method* is set to **-materi_velocity**, then the last calculated velocities will be used as slip direction (to be more precise, the projections on the ellipsoide surface will be used everywhere).

Default, if **safety_slip_ellipsoide_method** is not specified, *method* is set to **-safety_slip_ellipsoide**.

7.896 **safety_slip_ellipsoide_n** *index n*

See **safety_slip_ellipsoide**.

7.897 **safety_slip_ellipsoide_result** *index middle_x middle_y middle_z base1_x base1_y base1_z base2_x base2_y base2_z a b c safety_factor*

This record will after the calculation be filled with the ellipsoide for the critical surface and the safety factor.

7.898 **safety_slip_ellipsoide_segment_n** *index n*

With this record you can specify how many segments in an ellipsoide will be used in the integration of the safety factor. The ellipsoide is internally in tochnog integrated in a local ϕ and θ direction, over **safety_slip_combined_linear_segment_n** segments each. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_ellipsoide_n** is not specified, then 90 segments will be used.

7.899 **safety_slip_grd** *index switch*

If *switch* is set to **-yes**, Tochnog will read a slip surface from the file *index.grd*. The file is in .grd format, as used by the **surfer** program from **Golden Software**. Thus the format is:

```

DSAA
nx ny
xmin xmax
ymin ymax
zmin zmax
... (for first y specify z values for all x)
... (for second y specify z values for all x)
...
```

This **safety_slip_grd** is only available in 3D.

7.900 **safety_slip_grd_method** *index method*

With this record you can specify with which method the slip direction is chosen (this is the direction in which the slip shear force will be determined, to calculate the safety factor).

If *method* is set to **-safety_slip_grd_direction** the direction specified in **-safety_slip_grd_direction** will be used. If *method* is set to **-materi_velocity** the last calculated **-materi_velocity** directions will be used. If *method* is set to **-materi_displacement** the last calculated **-materi_displacement** directions will be used. If *method* is set to **-materi_velocity_integrated** the last calculated **-materi_velocity_integrated** directions will be used. If somewhere the direction is not specified by the above, because the used direction is a null vector, then Tochnog will ask you to specify **safety_slip_grd_method_direction** additionally, and then that direction will be used there.

Default, if **safety_slip_grd_method** is not specified, *method* is set to **-safety_slip_grd_direction**.

7.901 **safety_slip_grd_method_direction** *index dir_x dir_y dir_z*

See **safety_slip_grd_method**.

7.902 **safety_slip_grd_segment_n** *index n*

With this record you can specify how many segments in each part of the surface of the grd file will be used in the integration of the safety factor. In total the surface has $nx*ny$ parts; each of these parts will be integrated with $n*n$ segments. Default, if **safety_slip_grd_segment_n** is not specified, then *n* will be set to 10.

7.903 **safety_slip_multi_linear** *index x_first,0 y_first,0 x_first,1 y_first,1 . . . x_last,0 y_last,0 x_last,1 y_last,1 . . .*

This record specifies multi linear lines along which the safety factor should be calculated.

All data with *first* specifies the first multi linear line. The *x_first,0 y_first,0* specifies the first point of the first line piece of the first multi linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the first multi linear line which is also the first point of the second line piece of the first multi linear line, etc.

All data with *last* specifies the last multi linear line. The *x_last,0 y_last,0* specifies the first point of the first line piece of the last multi linear line, the *x_first,1 y_first,1* specifies the second point of the first line piece of the last multi linear line which is also the first point of the second line piece of the last multi linear line, etc. This last multi linear line should have an equal number of points as the first multi linear line.

With **safety_slip_multi_linear_n** you specify the number of multi linear lines that should be evaluated in the safety calculation; all multi linear lines to be evaluated will be put equidistant between the first multi linear line and the second multi linear line.

As a special option you can only specify data for the first multi linear line, and specify not data for the last multi linear line and not **safety_slip_multi_linear_n**; then only one multi linear line will be used.

See also **control_safety_slip**.

7.904 **safety_slip_multi_linear_n** *index n*

See **safety_slip_multi_linear**.

7.905 **safety_slip_multi_linear_result** *index x_0 y_0 x_1 y_1 ... safety_factor*

This record will after the calculation be filled with the multi linear line for the critical surface (for the multi linear lines circles with the same index).

7.906 **safety_slip_multi_linear_segment_n** *index n*

With this record you can specify how many segments in a line piece of a multi linear line will be used in the integration of the safety factor. A high number of segments gives more accuracy but is time consuming. A low number of segments is less accurate but fast. Default, if **safety_slip_multi_linear_segment_n** is not specified, then 10 segments will be used.

7.907 **safety_slip_set** *index index_0 index_1 index_1 ...*

This records defines the indices of safety geometries belong to a set. For all safety geometries of a set, the minimal safety factor will be determined.

As a special option you can also define a range.

7.908 **safety_slip_set_result** *index index safety_factor*

This record will be filled after the calculation with the minimal safety factor of the geometries in the set.

7.909 **slide_geometry** *index geometry_entity geometry_entity_index*

This record generates slide friction forces when a material slides over the geometry specified by *geometry_entity geometry_entity_index*.

This option comes handy when it is a priori known at which nodes sliding will occur, which is typically the case in an Eulerian calculation.

Also **slide_plasti_friction** should be specified.

See also **node_slide**.

7.910 **slide_plasti_friction** *index phi c*

This record specifies friction for the **slide_geometry** option. The maximum friction force between the material and the side surface equals $c + F_n * \tan(phi)$ where c is the cohesion, phi is the friction angle in radians and F_n is the normal force.

7.911 **slide_plasti_tension** *index sig_t*

This record specifies maximum tensile force for the **slide_geometry** option.

7.912 **slide_user** *index switch*

If *switch* is set to **-yes** the user supplied routine for slide friction is called.

See also the file **user.cpp** in the distribution.

7.913 **slide_damping** *index damping_n damping_t*

This specifies the normal damping and tangential damping for sliding. See also **control_slide_damping_apply**.

7.914 **slide_stiffness** *index stiffness_n stiffness_t*

This specifies the normal stiffness and tangential stiffness for sliding. See also **control_slide_stiffness_apply**.

7.915 **smooth** *dof_0 dof_1 ...*

With this option you can specify that solution fields should be smoothed; Tochnog will smooth away space oscillations in the field. By example, specify **smooth -pres** to smooth groundflow hydraulic head oscillations.

7.916 **smooth_factor** *factor*

This factor determines how strong the smoothing should be done. With *factor* is 0, there is no smoothing. With *factor* is 1, the smoothing is maximal. Default *factor* is 1.

You typically may want to experiment with this factor to find out what the optimal value is for you specific calculation.

7.917 **smooth_n** *number_of_smoothing*

Default the **smooth** operator will be applied once only. That means that dof oscillation in a node are only smoothed with the direct neighbour nodes. To spread that smoothing over more nodes, set the *number_of_smoothing* to a higher than 1 value; then the smoothing will be done *number_of_smoothing* times so that smoothing spreads over larger areas.

7.918 **solver** *solver_type*

You can set here the solver type to one of solvers as specified in **control_solver**. The solver set here holds for the entire calculation (as opposed to the **control_solver** which only holds for the corresponding time steps). In fact, each **control_solver** will be overwritten by a specified **solver**.

When using the bicg solver, consider also setting **solver_matrix_symmetric** to **-yes**, in order to speed up the speed of the bicg solver.

7.919 solver_bicg_error *error*

With *error* you set the termination error ratio between the initial and final error in the bicg iterations.

See also **control_solver_bicg_error**.

7.920 solver_bicg_restart *nrestart*

With *nrestart* you set the number of restarts in the bicg iterations.

See also **control_solver_bicg_restart**.

7.921 solver_bicg_stop *switch*

If *switch* is set to **-yes**, the calculation is stopped if the bicg solver does not converge. If *switch* is set to **-no**, the calculation is not stopped if the bicg solver does not converge.

See also **control_solver_bicg_stop**.

7.922 solver_matrix_save *switch*

If *switch* is set to **-yes**, the solver saves and applies the decomposed matrix, but not in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep. This can save CPU time, since further decompositions of the matrix are not required anymore (only backsubstitution to find the solution vector).

If *switch* is set to **-no**, the solver does not save the decomposed matrix.

If *switch* is set to **-always**, the solver saves and applies the decomposed matrix, even in case Tochnog thinks for some reason that the matrix needs to be decomposed at each timestep.

This option is only available in combination with the pardiso solver. See also **control_solver_matrix_save**.

7.923 solver_matrix_symmetric *switch*

If *switch* is set to **-yes** then, if needed, matrices are symmetrized so that less memory will be needed and a symmetrical equation solver can be used.

7.924 solver_pardiso_ordering *ordering*

See also **control_solver_pardiso_ordering**.

7.925 **solver_pardiso_out_of_core** *switch*

If *switch* is set to **-yes** the pardiso solver is called with a 'out of core' option. See for further the pardiso solver in the the intel mkl library.

7.926 **solver_pardiso_processors** *nproc*

Set the number of processors to be used by the pardiso solver. Only 1 or the maximum number of the computer is allowed, nothing in between.

7.927 **strain_settlement_parameters** *index time_global,start time_plus reference_creep_strain reference_time power_n lateral_factor*

With this option data items you can specify an extra vertical settlement creep strain. Think of geotechnics soil dumping as a typical example where after dumping some extra vertical straining shows up over time.

The vertical settlement creep strain of a soil particle is assumed to be:

$$\dot{\epsilon}_{zz} = \frac{\dot{\epsilon}_r}{1 + \left(\frac{t - t_{plus}}{t_r}\right)^n}$$

The user supplied parameters are: $\dot{\epsilon}_r$ as reference creep rate, t_{plus} , t_r as reference time and n as power constant. Creep strain starts when the global time t_{global} reaches *time_global, start*. So *time_age, start* can be used to set where in the creep strain curve the material will start with creeping. The time t in this equation is the time elapse after the material has become active (so the time after dumping the material, which typically is different for each finite element).

The horizontal creep strains $\dot{\epsilon}_{xx} = f\dot{\epsilon}_{zz}$ and $\dot{\epsilon}_{yy} = f\dot{\epsilon}_{zz}$ are assumed to be a lateral factor f times the vertical creep strain.

This **strain_settlement_parameters** should be combined with the **mesh_gravity_activate_time** option as follows:

```
...
mesh_activate_gravity_time 10 ...
mesh_activate_gravity_time_strain_settlement 10 -yes
strain_settlement_parameters 20 ...
...
```

The **mesh_activate_gravity_time_strain_settlement** indicates that the mesh activation should not be used by itself, but is only used to determine element activation times needed for the **strain_settlement_parameters** option.

See also **strain_settlement_element_group**.

7.928 **strain_settlement_element_group** *index element_group_0 element_group_1 ...*

This record specifies the element groups for which the **strain_settlement_parameters** with the same parameters will be used. As a special option you can use **-all**, such that all elements groups

will be used.

7.929 strain_volume_absolute_time *index time_0 volume_increase_absolute_0 time_1 volume_increase_absolute_1 ...*

See **strain_volume_element**.

7.930 strain_volume_element *index element_0 element_1 ...*

With the **strain_volume_*** data items you can specify an extra volumetric strain component which Tochnog should add to specified elements, element groups or a geometry. Think of geotechnics grouting as a typical example.

Use **strain_volume_element** to specify element numbers for which the volume strain should be applied. Use **strain_volume_element_group** to specify element group numbers for which the volume strain should be applied. Use **strain_volume_geometry** to specify a geometry for which the volume strain should be applied.

You can either specify relative volume strains (relative to the initial volume) or absolute volume changes. Use **strain_volume_relative_time** to specify a time versus relative volume strain diagram. These relative volume strains should be specified as percentage (thus, 100 would be a volume strain equal to the initial volume, so 100 percent extra volume). Use **strain_volume_absolute_time** to specify a time versus absolute volume increase diagram. These absolute volume increases should be specified as real volume (thus m^3 if you use would meter m as length unit in your input file). Exactly one of **strain_volume_relative_time** or **strain_volume_absolute_time** should be given in the input file, not both. At times outside **strain_volume_relative_time**, or **strain_volume_absolute_time**, the relative volume strain, or absolute volume increase, are assumed to be zero.

If none of **strain_volume_element**, **strain_volume_element_group** or **strain_volume_geometry** is given then the **strain_volume_relative_time** or **strain_volume_absolute_time** will be applied to all isoparametric elements.

The volumetric strain option presently is available only for small deformation analysis. The volumetric strain can be applied to isoparametric elements only. The volumetric strain is not available for membrane elements.

See also **post_strain_volume_absolute** and **post_strain_volume_relative**.

7.931 strain_volume_element_group *index element_group_0 element_group_1 ...*

See **strain_volume_element**.

7.932 strain_volume_geometry *index geometry_item_name geometry_item_index*

See **strain_volume_element**.

7.933 strain_volume_relative_time *index time_0 relative_volume_strain_0 time_1 relative_volume_strain_1 ...*

See **strain_volume_element**.

7.934 support_edge_normal *index stiffness_normal stiffness_tangential*

Distributed support of an edge (winkler foundation). The *stiffness_normal* specifies the normal stiffness of the support per unit length in 2D, and per unit area in 3D. The *stiffness_tangential* specifies the tangential stiffness. This option is meant for 2D and 3D calculations.

Also the record **support_edge_normal_geometry** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

See also **node_support_edge_normal_force**.

7.935 support_edge_normal_damping *index damping_normal damping_tangential*

Distributed damping at an edge. The *damping_normal* specifies the normal damping of the support per unit length in 2D, and per unit area in 3D. The *damping_tangential* specifies the tangential damping. This option is meant for 2D and 3D calculations.

If you want to use **support_edge_normal_damping** to absorb stress wave at the boundaries of the mesh (think of vibration or earthquake analysis), there are typical values to be used for the normal and tangential damping.

For absorbing boundaries the *damping_normal* typically should be set to $C_n \rho V_n$. The parameter C_n typically is chosen as 1. The ρ is the material density. The pressure wave velocity is $V_n = \sqrt{\frac{E_{oed}}{\rho}}$ with oedometric stiffness $E_{oed} = \frac{(1-\nu)E}{(1+\nu)(1-2\nu)}$ where E is the Young's modulus, and ν is Poisson's ratio. For absorbing boundaries the *damping_tangential* typically should be set to $C_t \rho V_t$. The parameter C_t typically is chosen as 0.25. The shear wave velocity is $V_t = \sqrt{\frac{G}{\rho}}$ with shear modulus $G = \frac{E}{2(1+\nu)}$.

Also the records **support_edge_normal** and **support_edge_normal_geometry** should be specified.

Attention: this option is only available for linear and quadratic isoparametric elements.

See also **control_support_edge_normal_stiffness_freeze** and **node_support_edge_normal_force**. See also **support_edge_normal_damping** for automatic specification of damping properties.

7.936 support_edge_normal_damping_automatic *index switch*

If you set *switch* to **-yes** this record generates damping just like the **support_edge_normal_damping** record. Now however you do not need to specify the damping properties yourself; they are calculated by Tochnog using the Young value E and the Poisson ratio ν from the isoparametric element attached to the support.

7.937 support_edge_normal_element_node *index element_0 element_1 ...*

Selects the element and local nodes for which the **support_edge_normal** record with the same *index* should be applied.

7.938 support_edge_normal_element_group *index element_group*

Restricts the element group to which the **support_edge_normal** record with the same *index* should be applied.

7.939 support_edge_normal_element_side *index element_0 element_1 ... side*

Selects the elements and local side number for which the **support_edge_normal** record with the same *index* should be applied.

7.940 support_edge_normal_factor *index a_0 a_1 ... a_n*

The same as **force_edge_normal_factor**, now however for the support stiffnesses (and not the force).

7.941 support_edge_normal_force_initial *index a_0 a_1*

This record allows you to specify an initial normal force in the support, linear varying in depth direction. The initial normal force actually is $a_0 + a_1 * y$ in 2D, or $a_0 + a_1 * z$ in 3D.

7.942 support_edge_normal_geometry *index geometry_entity_name geometry_entity_index*

Selects the area for which the **support_edge_normal** record with the same *index* should be applied. For example, **-geometry_line 1** can be used in 2D, indicating that the nodes on line 1 get the distributed support.

7.943 support_edge_normal_node *index node_0 node_1 node_2 ...*

Selects the nodes for which the **support_edge_normal** record with the same *index* should be applied. The *node_0* etc. specify global node numbers.

7.944 support_edge_normal_plasti_compression *index normal_force_minimum tangential_force_factor*

With *normal_force_minimum* you can limit the amount of compression force that a support can take. Any compression force lower than this *normal_force_minimum* will actually be set to *normal_force_minimum*. Typically you want to specify a negative value for *index normal_force_minimum*.

With *tangential_force_factor* you can model frictional slip in the tangential direction. The tangential force is limited to *tangential_force_factor* times the normal force. Larger tangential forces are not allowed.

This **support_edge_normal_plasti_compression** will only be used if the normal force does not exceed the maximum tension force as specified in **support_edge_normal_plasti_tension** or **support_edge_normal_plasti_tension_double**.

All forces are per unit length in 2D, and per unit area in 3D.

7.945 **support_edge_normal_plasti_friction** *index cohesion friction_coefficient*

With this record you can limit the amount of friction force that a support can take. The maximum allowed friction force is the *cohesion* plus the *friction_coefficient* multiplied with the absolute value of the normal force.

All forces are per unit length in 2D, and per unit area in 3D.

7.946 **support_edge_normal_plasti_tension** *index switch*

If *switch* is set to **-yes** and the normal force in the support is tension, then all forces are set to 0. This models gap building between the support and the element edge.

7.947 **support_edge_normal_plasti_tension_double** *index normal_force_maximum*

With *normal_force_maximum* you can limit the amount of tension force that a support can take. As opposed to **support_edge_normal_plasti_tension**, you can specify a non-zero value with this option. If a normal force higher than this *normal_force_maximum* occurs it will be set to *normal_force_maximum*, and tangential shear forces will be set to zero. Typically you want to specify zero or a positive value for *index normal_force_maximum*, although a negative value is also allowed.

Not both of **support_edge_normal_plasti_tension** and **support_edge_normal_plasti_tension_double** can be specified.

All forces are per unit length in 2D, and per unit area in 3D.

7.948 **support_edge_normal_plasti_residual_stiffness** *index factor*

In case of plasticity in a support you can require that Tochnog includes a part of the original elastic stiffness in the element stiffness matrix to get more stable iterations. The part of the original stiffness included needs to be specified with *factor*, between 0 and 1. The stiffness is only included in the matrix, and not in the right-hand-side; so it will only influence convergence behaviour, but not the final results if a sufficient amount of steps is taken. Default, if **support_edge_normal_plasti_residual_stiffness** is not specified, *factor* is set to 0.

7.949 **support_edge_normal_time** *index time load time load ...*

This record specifies a diagram with a multiplication factor for the support edge force. Linear interpolation is used to extend the *time load* values to the intervals between these pairs. Outside the specified time range a factor 0 is used.

If this record is not specified, a factor of 1 is applied at all times.

7.950 **target_item** *index data_item_name data_item_index number*

See also: **target_value**.

7.951 **target_value** *index value tolerance*

This allows for testing the results of the calculation. Typically, *data_item_name* is **-node_dof** but also other data items can be tested. The record with index *data_item_index* will be tested. If *data_item_name* is **-node_dof** then *number* can be **-velx**, **-temp**, etc. (see **dof_label**); else, for example, *number* is 3 states that the fourth value needs to be checked. The result should not differ more from *value* than *tolerance*.

For a calculation with no problems, the tochnog.log file contains a line stating that the calculation did start followed by a line stating that the calculation did end. If this is not precisely the case, some problem did occur or the targeted results differ too much. In the example below it is checked that the pressure in node 6 does not differ more than 1.10^{-5} .

```
target_item 0 -node_dof 6 -pres
target_value 0 1.2 1.e-5
```

The checked value, 1.2 in this case, has been found from a previous computation that is regarded as reliable. The present computed value is compared with the earlier one. If they agree within the specified tolerance, 1.e-5 in this case, then Tochnog is silent. If they do not, then Tochnog writes an error message into the file "tochnog.log".

7.952 **time_calculation** *elapsed_time_in_seconds*

Elapsed computer time up to moment of printing (wall clock time).

7.953 **time_current** *current_time*

Current time in calculation.

7.954 **timestep_predict_velocity** *switch*

Normally tochnog will use as prediction for velocities in a timestep the previous calculated velocities from the previous timestep.

However, if there is no inertia, and **convection_apply** is **-no** tochnog will use as prediction for velocities in a timestep a zero velocity.

You can require that tochnog does the normal prediction from the previous timestep however by setting *switch* to **-yes**; you typically want to do that in eulerian calculations.

7.955 **timestep_iterations_automatic_apply** *switch*

If *switch* is set to **-no** any **control_timestep_iterations_automatic** records will be neglected.

7.956 tochnog_version *index version_number day month year*

This record contains the version number, the build day, the build month and the build year.

7.957 tochnog_version_beta *index switch*

This record contains the beta indicator. If the indicator is **-yes** the executable is a beta version. If the indicator is **-no** the executable is not a beta version.

7.958 truss_rope_apply *switch*

If *switch* is set to **-no**, any truss rope data in the input file will be ignored. This is done for all timesteps.

This option is convenient for testing your input file just linear, without the need to outcomment each and every part with truss rope data. See also **control_truss_rope_apply**.

7.959 volume_factor $a_0 a_1 \dots a_n$

This data item defines a polynomial in space in 1D or 2D. The polynomial specifies the cross-sectional area (in 1D) or the thickness (2D) as function of the global x coordinate (1D) or the global x,y coordinates (2D). For example, in a 1D solid calculation it can be used to specify varying cross-sectional areas of bars, or in a 1D flow calculation it can be used to specify the cross-sectional area of a channel.

In 1D the polynomial is $a_0 + a_1x + a_2x^2 + \dots$. In 2D the polynomial is $a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^3 + a_7x^2y + a_8xy^2 + a_9y^3 + \dots$

If this record is not specified, the cross-sectional area is 1 (1D) or the thickness is 1 (2D).

See also **volume_element_factor**.

7.960 volume_factor_x $x_0 fac_{01} x_1 fac_{12} \dots x_n$

This specifies an in x-direction changing volume factor for elements. Left from x_0 the factor is 1. From x_0 to x_1 the factor is fac_{01} . Etcetera. And right from x_n the factor is 1 again.

7.961 end_data (last record of data part)

8 Runtime file

You can use a runtime file to give to Tochnog data on the fly (while it is running). The runtime file will be read at the start of each time step. The runtime file needs to have the same name as the input file, with the extension **run** instead of **dat** however. Suppose the name of the normal input file is **beam.dat**, then the name of the runtime file is **beam.run**. The runtime file always needs to be ended with two **end_data** statements.

As a typical example you can use this runtime file when you are doing a long calculation and you decide while the calculation is running that you want extra output. Suppose the normal input file **tochnog.dat** contains:

```
...  
control_timestep 100 ...  
...
```

Then you can decide to get some extra GID plotting files, while Tochnog is already running, by using the runtime file **tochnog.run** with:

```
control_print_gid 100 -yes  
end_data end_data
```

When you want to de-activate the printing of GID files again then set the runtime file to:

```
control_print_gid 100 -no  
end_data end_data
```

As a special option, you can use **exit_tochnog -yes** in the runtime file; then Tochnog will exit the calculation after printing the complete database and GID files.

After the runtime file is read, it will be automatically deleted by Tochnog.

9 Interaction analyzes and advanced analyzes

9.1 Fluid-structure interaction

If a solid construction interacts with a fluid, both the solid and fluid can be modeled with the materi equation. Interaction forces between solid and fluid will automatically be generated. If required, a temperature field may be imposed. An example of a input file is given below

```
...
materi_velocity
materi_stress
condif_temperature
end_initia
...
element_group -ra -from 0 -to 100 -ra 1
element_group -ra -from 101 -to 200 -ra 2
...
type 1 -materi -condif
group_materi_elasti_young 1 ...
group_materi_memory -updated
group_condif_conductivity 3 ...
...
type 2 -materi
group_materi_elasti_compressibility 2 ...
group_materi_viscosity 2 ...
group_materi_memory -updated_linear
group_condif_conductivity 2 ...
...
```

Elements 0-100 are solids (with temperature) and elements 101-200 are fluids (with temperature).

9.2 Consolidation analysis: ground water flow in deforming solid

The ground water flow equation can be combined with the materi equations. The solid will deform due to the ground water flow pressure gradient and ground water flow pressure will change due to solid volume changes. An example of a input file is given below

```
...
materi_velocity
materi_stress
groundflow_pressure
end_initia
...
groundflow_consolidation_apply -yes ...
groundflow_density ...
groundflow_phreatic_level ...
...
group_type 0 -materi -groundflow
group_materi_elasti_young 0 ...
```

```

group_materi_memory -updated
group_groundflow_capacity 0 ...
...

```

The stresses as initialized by **materi_stress** are effective stresses. Internally the program calculates with total stresses (effective stress + total pressure) in the material equilibrium equation. You can obtain the total stresses for postprocessing by means of the **post_calcul** option.

To account for the gravitational stresses, use a density ρ_{sat} in the **group_materi_density** record. Here ρ_{sat} is the saturated density of the groundwater-soil mixture (mass of soil + water per unit volume of the soil-water mixture). Also specify the gravitation in the **force_gravity** record and, if required, also the **force_gravity_time** record to apply the gravitation slowly.

9.3 Heat transport in ground water flow

Heat transport in a ground water flow can be analyzed by combining the convection and diffusion of heat equation with the ground water flow equation. Now the velocity in the convection and diffusion of heat equation is taken from the groundflow velocity field ($\beta_i = v_i^g$) if **groundflow_velocity** is initialized. An example of a input file is given below

```

...
groundflow_pressure
groundflow_velocity
condif_temperature
end_initia
...
type 0 -groundflow -condif
group_groundflow_compressibility 0 ...
group_condif_conductivity 0 ...
...

```

If both **materi_velocity** and **groundflow_velocity** are initialized, $\beta_i = v_i + v_i^g$.

9.4 Heat transport in materials

Heat transport in a material can be analyzed by combining the convection and diffusion of heat equation with the materi equations. In this way thermal stresses or heat induced convection can be analyzed. Now the velocity in the convection and diffusion of heat equation is taken from the velocity field ($\beta_i = v_i$). An example of a input file is given below

```

...
materi_velocity
materi_stress
condif_temperature
end_initia
...
type 0 -mater -condif

```

```
group_materi_elasti_young 0 ...  
group_materi_expansion 0 ...  
group_materi_memory 0 -updated  
group_condif_conductivity 0 ...  
...
```

9.5 Restart a calculation

You can use a dbs file to restart a calculation. In fact, a dbs file is an input file itself. It contains the record **icontrol** which contains the last control index actually performed with the previous calculation. You can add more **control_*** records and start the file again; it will then continue with these new **control_*** records.

You cannot use dbs files with contain **control_repeat** for restarting a calculation.

10 Final topics (input trouble, save memory /cpu time, ...)

10.1 Environment symbols

Records with a length of 1, and no index, you can also set via an environment symbol. You need to use capital characters in doing so. Typical examples are

- **PROCESSORS 4**
- **PRINT_GID_CALCULATION -no**
- **PRINT_GMSH_CALCULATION -yes**
- **PRINT_NODE_GEOMETRY_PRESENT -yes**

In windows set environment symbols in your advanced system settings. In a linux bash shell set environment symbols in your `.bashrc` file (eg **export PROCESSORS=4**).

10.2 Checking your geometry_* records

Set **print_node_geometry_present -yes** and set **print_element_geometry_present -yes**. Then look with **gmsb** if the geometries are like you want.

10.3 Continuing an analysis

- Copy the database from the previous calculation to a new file, e.g. **new.dat**.
- Run a new calculation with **new.dat**.

This can also be done with a database that is written as intermediate database in a previous calculation, by example directly after gravity. See also **icontrol**.

10.4 Use -node as geometry entity.

As a special option you can use a node as a geometrical entity. By example the following imposes a boundary condition on the temperature of node 6:

```
bounda_dof 10 -node 6 -temp
```

Notice that **-node 6** is used in the format of a geometry entity.

10.5 Use -geometry_list as geometry entity.

As a special option you can use a list as a geometrical entity. By example the following imposes a boundary condition on the nodes of geometry list 6:

```
geometry_list 6 54 43 26 38 62
bounda_dof 10 -geometry_list 6 -temp
```

10.6 List input files with options

You can search for input files in your distribution which contain multiple words. By example change to the test/other directory. Suppose you want to see in which files you can see transient consolidation in a deforming soil.

In linux use the following command to list input file:

```
grep -il materi_velocity *.dat | xargs grep -il groundflow_capacity | xargs grep -il groundflow_consolidation.
```

In MS Windows use:

windows explorer - Search - Advanced options - File contents

and search for

materi_velocity AND groundflow_capacity AND groundflow_consolidation.

10.7 Geometrically linear material

Either do this:

- Initialise **-materi_velocity** and **-materi_displacement**
- Use **-total_linear** for the material.

or do this:

- Initialise **-materi_velocity** and **-materi_velocity_integrated**
- Use **-fixed_in_space** for **mesh**
- Use **-updated_linear** for the material.

10.8 Dynamic calculations

Dynamic calculations are triggered by setting **inertia_apply -yes**. Take care that you have specified all required data, like material density, etc. Also take care that you use sufficient small timesteps to prevent artificial numerical damping.

In case you need to be sure that there is no artificial numerical damping, you can use the following piece of input file. Also see **dynamic2.dat** in the test calculations in your distribution for an example.

```
...
materi_displacement
materi_velocity
materi_acceleration
end_initia
```

```

...
inertia_apply -yes
...
control_timestep .....
control_timestep_iterations ... 1
control_timestep_iterations_extra ... -no
...

```

In case you can accept a bit damping but not too much use:

```

...
materi_displacement
materi_velocity
materi_acceleration
end_initia
...
inertia_apply -yes
...
control_timestep .....
control_timestep_iterations_extra ... -no
...

```

To get damping quite similar to rayleigh damping in structural dynamics use:

```

...
group_materi_damping ... (similar to rayleigh damping mass term, use alpha *
material density )
group_materi_viscosity ... (similar to rayleigh damping stiffness term, use beta *
material young )
...

```

10.9 Input file syntax

- If you don't understand the syntax of an option, please look in the tochnog/test/other directory for example files. Under linux search for the command, eg **grep control_print_filter *.dat** to get example files with **control_print_filter**.

10.10 Check large calculations

- Set both **solver -none** and **linear_calculation_apply -yes** ; run and check in gid the boundary conditions, forces, change of element groups, etc. In a complex model you can check geometries that you use by imposing an artificial boundary on them, eg **bounda_dof ... -temp** with value 1, and look in gid if you see that boundary condition showing up at the correct nodes.
- Only set **linear_calculation_apply -yes** ; run and check linear solution fields.
- Do not set anything special ; run and check solution fields.

10.11 Diverging calculations

- Try the linear elements **-bar2**, **-quad4** , **-tria3**, **-hex8** and **-tet4** in stead of quadratic elements.
- Try **solver_matrix_save -no** (always setup new system matrix)
- Try **group_materi_plasti_mohr_coul_direct** i.s.o. **group_materi_plasti_mohr_coul**
- Try small fixed timesteps (do not use automatic time stepping).
- Try more iterations with **control_timestep_iterations**.
- Try a lower interface stiffness.
- Try higher water capacity in calculation with consolidation (so water less stiff, anyway not too stiff relative to soil)).
- Set **group_interface_materi_residual_stiffness** to 1.

10.12 Saving CPU time

- Check that the computer doesn't swap to disk (use top in linux, and task manager in windows). In case of swapping lower memory using the section 'Saving computer memory'.
- Post data items (**post_point**, etc.) slow down the calculation. Skip them if you want to spare time.
- Printing (**control_print**, etc.) can substantially slow down the calculation. Only a **control_print index -time_current -post_node_rhside_ratio** will not slow down the calculation.

10.13 Saving computer memory

Try the following steps, in order of priority:

- **solver_matrix_symmetric -yes**.
- **processors 1**.
- **solver -matrix_iterative_bicg**.
- **dof_element_dof -no**.
- Use **bounda_alternate**.
- Don't use extreme large indices (since memory is allocated for all indices).

You only should do steps as needed. By example, if **solver_matrix_symmetric -yes** solves the memory problems you should not do any of the further steps; etc.

10.14 Inaccurate results

- Set the interface stiffness to about 10 times the neighbouring element young divided by the neighbour length.
- If a structure is submerged in water, eg a one-side submerged dam, you need to impose the correct pressure condition; but you also need to impose the water loading by a **force_edge_water**.

10.15 Element sides

This sections defines node numbers for element sides 0, 1, ... respectively.

For a **bar2** element the sides have the nodes numbers 0 and 1.

For a **tria3** element the sides have the nodes numbers 0,1 and 1,2 and 2,0.

For a **tria6** element the sides have the nodes numbers 0,1,2 and 0,3,5 and 2,4,5.

For quad elements the sides are in the order below, upper, left, right; see the pictures in **elements**.

For hex elements the sides are in the order below, upper, front, back, right, left; see the pictures in **elements**.

For a **tet4** element the sides have the nodes numbers 0,1,2 and 0,1,3 and 1,2,3 and 0,2,3.

For a **tet10** element the sides have the nodes numbers 0,1,2,3,4,5 and 0,1,2,6,7,9 and 2,4,5,7,8,9 and 0,3,5,6,8,9.

For a **prism6** element the sides have the nodes numbers 1,2,3 and 4,5,6 and 1,2,4,5 and 0,2,3,5 and 0,1,3,4.

For a **prism15** element the sides have the nodes numbers 0,9,1,11,10,2 and 3,12,4,14,13,5 and 0,9,1,6,7,3,12,4 and 1,10,2,7,8,4,13,5 and 0,11,2,6,8,3,14,5.

For a **prism18** element the sides have the nodes numbers 0,1,2,3,4,5 and 12,13,14,15,16,17 and 0,1,2,6,7,8,12,13,14 and 2,4,5,8,10,11,14,16,17 and 0,3,5,6,9,11,12,15,17.

10.16 Badly shaped elements

Each element should have at maximum one common side with a neighbouring element. By example two neighbouring quad4 elements have only one common side in a proper element mesh; if the neighbouring quad4 elements have two sides in common, the elements are badly shaped.

Some tochnog options will not work correctly if the mesh contains badly shaped elements.

10.17 Further remarks.

The records **force_edge**, **force_edge_normal**, **force_edge_projected**, **force_volume**, **condif_heat_edge.no**, **condif_convection_edge_normal** and **condif_radiation_edge_normal** are evaluated inside the element loop. Hence, the resulting nodal forces only get their values after a timestep is performed (since the element loop is performed in time steps).

10.18 External superlu solver.

Tochnog professional may use SUPERLU as solver. For SUPERLU the following holds (copied from SUPERLU documentation).

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11 User supplied subroutines

Several skeleton user supplied subroutines are available in the file **user.cpp**. As a special option you can use an ABAQUS **umat.f** (ABAQUS is a trademark of Dassault Systemes; see [HTTP://www.abaqus.com](http://www.abaqus.com) for the ABAQUS homepage). See also **group_materi_umat** in this manual.

We only supports **user.cpp** and **umat.f** on linux 64 bit, with specific compilers. We use ourselves always the latest linux mint 64 bit; if you want to use the user supplied routines it is convenient to also use the same operating system in order to prevent compiling and linking problems.

We do not support any compilation, linking or run-time problems with user supplied routines.

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